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EVALUATION OF METHODS OF REDUCING COMMUNITY NOISE IMPACT AROUND SAN JOSE MUNICIPAL AIRPORT

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16. Abstract

A computer simulation of San Jose Municipal Airport was made of the airport noise impact on the surrounding communities. Alternate operational procedures, improved technology, and land use conversion were evaluated as methods of reducing community noise impact in the airport vicinity. In addition, a constant density population distribution was analyzed for possible application to other airport communities with fairly uniform population densities and aircraft operational patterns similar to San Jose.

Excellent agreement was found when calculated noise exposure values were compared to measured values from eight remote monitoring sites around San Jose.

Two segment approaches and thrust cutbacks on takeoff were found to be very helpful in reducing community noise impact; however, these procedures cannot reduce the noise very near the airport.

Takeoff noise was found to be the major nuisance, even at San Jose, where the downtown area lies below the approach path.

The introduction of sound absorption material (SAM) was found to reduce community noise annoyance by over 25%, and the introduction of refan was found to reduce community annoyance by over 60%. Replacing the present aircraft operating at San Jose by DC-10-10's was found to reduce the noise problem to very small proportions, and the introduction of an advanced technology twin was found to essentially eliminate the San Jose community noise problem.

As an alternative to aircraft noise reduction, the cost of acoustically insulating the homes within the present San Jose noise impact boundary is about $10 million. A tabulation of the market values of these homes showed that the total cost of buying up these residences is over $50 million.

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Authors' Note

This is the second printing of "Evaluation of Methods of Reducing Community Noise Impact Around San Jose Municipal Airport." Please note that additions have been made to the original study, including 1) clarification of the way S.A.M. and refan were simulated, 2) recent published data showing results of flight tested refanned DC-9 aircraft, and 3) modifications of DC-10 and DC-X-200 flight profiles, and the noise results dependent thereon.

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SUMMARY

A computer simulation of San Jose Municipal Airport was made to study the airport noise impact on the surrounding communities. After a review of the many existing noise level indices, Noise Exposure Forecast (NEF), used widely in the past, was compared with Day-Night Level (L_{DN}), chosen by the EPA to be used in the future and found to yield similar results. L_{DN} was then used to evaluate alternate operational procedures, improved technology, and land use conversion as methods of reducing community noise impact in the airport vicinity. In addition to the San Jose analysis using specific census tract data, a constant density population distribution was also analyzed for possible application to airport communities with fairly uniform population densities and aircraft operational patterns similar to San Jose, i.e., short to medium range flights using primarily two and three engine JT8D powered aircraft.

NEF and L_{DN} were found to differ by a nearly constant distance-dependent value. Using L_{DN}, excellent agreement was found when calculated noise exposure values were compared to measured values from eight remote monitoring sites around the airport.

Two segment approaches and thrust cutbacks on takeoff were found to be very helpful in reducing community noise impact; however, these procedures cannot reduce the noise very near the airport.

The introduction of sound absorption material (S.A.M.) was found to reduce community annoyance, (a statistical approximation of the number of people highly annoyed by aircraft noise), by over 25%, and

the introduction of modified engines (refan) was found to reduce community annoyance by over 60%. Replacing the present aircraft operating at San Jose on a plane per plane basis by DC-10-10's (which approximately doubles the passenger capacity) was found to reduce the noise problem to very small proportions, and similarly, the introduction of an advanced technology twin was found to essentially eliminate the San Jose community noise problem. The assumed advanced twin would increase present passenger capacity by about 50%.

A tabulation of the market values of the homes within the present San Jose noise impact boundary showed that the total cost of buying up these residences is over $50 million. The cost of acoustically insulating all these homes is about $10 million. These costs, if extrapolated to a nation-wide scale, dwarf the costs of improved technology.

Takeoff noise was found to be the major nuisance, even at San Jose, where the downtown area lies below the approach path.

The results discussed above are summarized in Figure 18.

INTRODUCTION

In the last twenty years, the City of San Jose has been one of the fastest growing cities in the country. Growing along with the city, and in some areas incompatibly, has been San Jose Municipal Airport. Downtown San Jose borders directly on the airport's south end, and the cities of Milpitas and Santa Clara, also experiencing this rapid growth, lie just to the northeast and west, respectively, of the airport (Figures 1,2). For these communities, the airport poses a serious environmental noise problem, the possible solutions to which are the focus of this study. Much of this work also applied to community noise impact reduction in general.

The oft stated "reduce the noise at its source" is the most desirable and most effective way of reducing aircraft noise and its community impact. Two methods of source noise reduction (or retrofitting) for older, noisier aircraft are: 1) the installation of sound absorption material (S.A.M.) in the nacelles of JT3D (707, DC-8) or JT8D engines (727, 737, DC-9), and 2) the replacement of the existing fan stages in JT8D engines with a larger diameter single stage (refan), plus acoustic treatment of the nacelle. S.A.M. absorbs acoustic energy, while refan results in increased airflow, a higher bypass ratio and lower noise from the primary exhaust flow. A third method is the use of new engines with higher bypass ratios similar to the JT9D, CF-6 and RB-211 engines used in today's wide bodied 747, DC-10 and L-1011 aircraft. Unfortunately, the introduction of S.A.M. or refan retrofit on a small scale poses many political problems; thus, if either option were to be implemented, it would be for the entire United States JT3D

and/or JT8D fleet - nearly 2000 aircraft. The EPA has estimated the total cost of S.A.M. for these aircraft to be $650,000,000, and S.A.M. for the JT3D's plus refan for the JT8D's to be $2.2 billion (Reference 12). These costs compromise the desirability of source noise reduction and are an especially serious problem for the airlines in this difficult economic period. Government subsidization would speed up the implementation of these options.

Another approach to reducing noise impact is through the use of alternate operational procedures - two segment approaches, thrust cutbacks on takeoff, and flying curved approaches over relatively sparsely populated areas. These procedures can help the people a few miles or more from the airport, but closer to the runway a full-power takeoff and a straight-in 3° approach must be maintained. Furthermore, before these procedures are adopted, the airline pilots must accept them as standard. The advent of microwave landing systems would simplify the adoption of alternate procedures on approach.

Another, and in heavily built-up areas least desirable, solution to the problem is the development of a compatible land use for noise impacted areas. This may consist of buying up residential areas for conversion to commercial, industrial, or agricultural use, or the acoustic insulation of these homes. These costs on a mass scale may be prohibitive, and worse yet, the inconvenience (to say the least) of moving one's household should be taken into account. However, as a last resort for heavily impacted areas near the airport, land use conversion is a possible solution.

To improve understanding of these problems, this study has examined

in detail the noise impact and potential reductions of this impact on the San Jose Airport community. In addition, in the course of the work, the many aircraft noise indices were reviewed, in particular, community response ratings. Enough of these indices (i.e., CNEL, NEF, L_{DN}, NNI, CNR) exist to cause substantial confusion. In light of this, Noise Exposure Forecast (NEF), used widely in the past, was compared (in the Appendix) with Day-Night Level (L_{DN}), the index chosen by the Environmental Protection Agency to be used in the future. L_{DN} was used in this study to determine the numbers of people exposed to, and highly annoyed by aircraft noise.

METHODOLOGY

Airline schedules for San Jose Municipal Airport, aircraft operational and flight path data and aircraft noise characteristics were used with 1970 U.S. Census Tract data to determine the number of people exposed to and highly annoyed by the aircraft operations at the airport. Alternate operational procedures, improved technology, and land use conversion were evaluated as methods of reducing community annoyance around the airport. For each alternative operational procedure, a constant density population distribution was analyzed in addition to the census data analysis. This provides a comparison with other studies in which the constant density assumption was also made, and allows application to airports with fairly even population distributions. In addition, contours of L_{DN} = 55, 65, and 70 were plotted for each alternative.

In determining the number of people exposed to and highly annoyed by aircraft noise for aircraft equipped with S.A.M. or refanned engines, it was assumed that the incremental noise reduction due to S.A.M. was 2 db on takeoff and 5 db on approach while the reductions due to refan were taken as 8 db for both takeoff and landing. Since these data are not well established, the effects of S.A.M. or refan, or any other improved technology, are also shown by showing the effects of reducing the source noise level data of the aircraft by increments of 2, 5, 8 and 12 db on takeoff and/or approach. This allows the reader to determine the benefits due to any modification one chooses to examine.

The total cost of acoustic insulation of the homes within the

San Jose noise impact boundary is based on the number of noise impacted homes (as determined by data from the Santa Clara County Tax Assessment Office) times the cost of insulating a typical home (Reference 11). Finally, the total value of the noise impacted homes was estimated using the assessed values of the homes within the noise impact boundary.

The major tool used to evaluate the impact of noise reduction is a NASA/DOT noise contour computer program developed originally under a DOT contract with Serendipity, Inc. The input for this program is the number of daily flights for each aircraft type (i.e., 707, DC-9, DC-8 S.A.M., etc.), their flight paths, and the experimentally determined variations of sound level with distance for each aircraft, the latter taken from Reference 1. For this study the number of daily operations was obtained by taking the total number of operations during September, 1974 at San Jose, and dividing by the number of days in the month. This data is shown in Table 1. In the past year, the number of daily operations at San Jose has increased by about 5-10%, not a large increase in terms of noise, and the data in Table 1 closely approximates the 1975 airport operational profile. However, should this annual growth rate continue, the operational data used would no longer be applicable for future years.

The aircraft flight paths associated with these operations were arrived at by: 1) determining representative ranges from the distribution of flights by range (stage length) from Reference 5, as shown in Figure 3; 2) calculating the aircraft's takeoff weight for that range (from Reference 6); and 3) determining the aircraft's flight path as a function of its takeoff gross weight (References 6, 7, 8 and 15).

The resulting input, from Table 2 and Figure 3, assumes that seven 727's takeoff with a 1500 n. mi. range at 165,000 lbs. takeoff gross weight; 25 727's takeoff with a 300 n. mi. range at 140,000 lb. takeoff gross weight; all the 737's and DC-9's takeoff with a 300 n. mi. range at 91,000 and 89,000 lb. takeoff gross weight respectively; and all the 707's and DC-8's takeoff at their maximum takeoff gross weights.* The normal approach flight path is independent of range and is assumed to be along a 3° glide slope, the data taken from Reference 8.

All operations were assumed to be straight in and straight out, for two airport configurations: 1) 100% of the operations to the north, simulating good weather, and 2) 15% of the operations to the south, as on an unusually windy day, typically in winter. Actually, northerly takeoffs turn to the east after takeoff over San Francisco Bay, but at an altitude where the noise impact has become small. The two-segment approach data (Table 3) assumes a 6° glide slope with an 800 ft. intercept to a 3° glide slope. The thrust cutbacks shown in Table 4 are for a cutback to about 70% thrust at around 1500 ft. altitude. This data comes from input to a similar noise contour computer program at NASA-Lewis Research Center.

The census data was input as a set of coordinates of the centroids of census tracts, with their associated populations (see Figures 1, 2). Being careful to cover all possible areas where people could be "exposed" to significant levels of aircraft noise required census data that ranged out to a point eighteen miles from the airport under the approach path (Figure 2). Community reaction to aircraft noise is based on the EPA's

*Actually the DC-8 and 707 do not use maximum takeoff weight out of San Jose, but the low frequency of operation of these aircraft makes the error on total noise exposure insignificant.

"Levels" document (Reference 3), which gives an approximate relationship between noise exposure, in L_{DN}, and percent of the population highly annoyed, (%HA).* Thus

%HA (Percent of population highly annoyed) = 1.8 (L_{DN} - 46)

This shows that an L_{DN} = 46 or below implies zero people highly annoyed. Thus the L_{DN} = 46 contour is the annoyance threshold, and "exposure" to aircraft noise is defined as living at a point where the L_{DN} exceeds the annoyance threshold.

The Adopted Noise Regulations for California Airports (Reference 10) are stated in terms of Community Noise Equivalent Level (CNEL), almost identical to L_{DN},** and usually taken to be so. The goal of these regulations is that by 1985, the CNEL = 65 (L_{DN} = 65) contour not enclose any residential areas. This contour is referred to as the "noise impact boundary," and should be distinguished from the L_{DN} = 46 contour. An L_{DN} of 65 corresponds to 34.2% of the population highly annoyed.

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*EPA recommends % HA = 2.0 (L_{DN} - 50), although a plot of percent highly annoyed versus L_{DN} shows % HA = 1.8 (L_{DN} - 46). The expressions are equivalent for L_{DN} = 86 and differ by 4% at L_{DN} = 65. It should be noted that as more research and social surveys are done, it can be expected that these annoyance functions will be replaced by newer ones based on a larger body of data.

**In the form shown in the Appendix, $CNEL_i = SEL_i + 10 \log (N_D + 3 N_E + 10 N_N) - 49.36$ where N_E is the number of evening flights from 7:00 to 10:00 p.m.

RESULTS

NOISE PREDICTION

A comparison of calculated L_{DN} values with measured CNEL values (CNEL $\cong L_{DN}$) at the eight remote monitoring sites around San Jose Airport shows excellent agreement. Comparing the calculated noise exposure in the 100% north column in Table 6 with the measured September values (good weather, nearly all takeoffs on 30L, northerly), and the calculated 85% north, 15% south column with the measured December values, one sees that the largest deviation (out of 15 comparisons) is just 2.8 db. Sites 3 and 4, with the highest and lowest values of L_{DN} show the best agreement, indicating good correlation over a wide range of values. The average deviation

$$\frac{\sum_{i=i}^{\text{no. of sites}} \left(L_{DN_{i}\,\text{calc.}} - CNEL_{i\,\text{meas.}} \right)}{\text{no. of sites}}$$

is 1.44 db for the September values and 1.39 db for the December values. Evidently, the computer simulation of San Jose Airport was good, giving the following results credibility.

OPERATIONAL PROCEDURES

As mentioned earlier, the airport lies between downtown San Jose on the south, and Milpitas, Santa Clara, and San Francisco Bay on the north (Figures 1, 2). Usually, approaches are over the city, takeoffs are over the Bay. With all operations to the north, (Table 7) the use

of two segment approaches reduces exposure, the number of people exposed to aircraft noise, by 18.4%, and annoyance, the number of people highly annoyed, by 14.4%. The contours (Figure 4) show that the two segment approach doesn't help near the airport where the aircraft are on a 3° glide slope. The improvement comes from the areas further from the airport under the 6° glide slope, as evidenced by the cut off of the L_{DN} = 55 contour (Figures 4, 5). The area of the L_{DN} = 46 contour is reduced by 14% by the two-segment approach, much of this reduction coming from populated parts of San Jose.

A thrust cutback on takeoff lengthens and narrows the outer noise contours (see Figures 4, 5). The L_{DN}= 46 contour area is increased slightly, but the narrowness of the contour results in a modest (5-6%) reduction in both exposure and annoyance. The combination of the two-segment approach and thrust cutback on takeoff resulted in a 24.5% reduction in people exposed, and a 19.9% reduction in people highly annoyed.

Turns over lightly populated areas on approach were investigated to reduce the noise impact. However, the improvement obtained by this procedure was small and in one case there was actually an increase in the number of people highly annoyed (Figure 6).

With 15% of the operations to the south, the effects of takeoff dominate the contours (Figure 7). A comparison of the 100% north contours with the 85% north/15% south cases shows the latter with a slightly wider and smoother shape, the width due to the southerly takeoffs and the smoothing due to the approaches from the north. These small changes in contour shape are enlarged when the exposed population

is taken into account (Tables 7,8). With 15% southerly takeoffs, 35,000 more people (a 25% increase) are exposed, and nearly 6000 more, up 27%, are highly annoyed. The improvements due to thrust cutbacks on takeoff are thus magnified, and those due to two segment approaches are reduced.* The total improvement using both procedures is now greater (25%) but many more people are still exposed (25,000 or 24% more) and highly annoyed (3000 or 18% more) with the southerly operations than with all flights to the north.

The constant density analysis with unidirectional operations (Table 9) shows that a thrust cutback on takeoff slightly increases the area of the $L_{DN} = 46$ contour with a corresponding increase in community noise exposure. However, in the area where the contour is elongated, the L_{DN} is reduced to such a low value that with a constant population distribution, community annoyance is reduced by over 9%. A two segment approach helps greatly in reducing both exposure and annoyance.** The combination of two segment approach with a thrust cutback on takeoff reduces exposure to aircraft noise by 12.6%, and reduces annoyance by 19.8%.

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*The 0.00 in the exposure column is a result of inputting the census data in the form of people at distinct points. The same points were exposed in each case, thus 0.00 improvement. Because of this method of input the annoyance numbers are probably a somewhat better indicator of community response.

**A word of caution in interpreting the numbers in Table 9: the population density used was 7960 person/sq. mi. (Reference 9), a figure accurate for San Jose proper but not for large sections of the remainder of the $L_{DN} = 46$ contour. The meaningful figures in Table 9 are in the percent improvement column, and the use of 7960 persons/sq. mi. was only meant as a yardstick.

With an 85%/15% directional split, the results are very similar to the unidirectional case. A thrust cut looks favorable in terms of reduced annoyance, and the two segment approach gives a reduction of 9 to 11% in community noise exposure and annoyance. The combination of the two procedures gives a 13% reduction in people exposed, and a 22.1% reduction in people highly annoyed.

IMPROVED TECHNOLOGY

Tables 11 and 12 and Figures 8 through 17 show the improvements in contour area, community noise exposure, and community annoyance with source noise reductions of 2, 5, and 8 and 12 db on the JT8D aircraft operating at San Jose. About 2% of the equivalent operations at San Jose are JT3D powered (see Table 1), so this slightly hinders the improvements shown. Constant density cases were not analyzed, as people exposed in that case are strictly a function of contour area (area times population density), and annoyance is also a strong function of contour area, the reductions in which are shown.

The use of Figures 8 - 17 is as follows. Suppose you think S.A.M. (JT8D) treatment will give reductions of 2 db on takeoff and 8 db on approach. Find the curve labelled "TAKEOFF, with an 8 db approach reduction," and pick off the points with a 2 db reduction, or alternately find "APPROACH, with a 2 db takeoff reduction," and pick off the points showing an 8 db reduction. Some interpolating may be necessary for certain combinations of takeoff and approach reductions. These curves may be used for any type of JT8D noise reduction, or the introduction of new aircraft that would replace the 737's, 727's, and DC-9's on a plane for plane basis.

Two points deserve special attention. First, the improvements in noise impact due to takeoff noise reduction are far greater than those due to approach reduction in both airport configurations. Second, the law of diminishing returns (in its acoustic form) comes into play, as improvements tends to level off with reductions of more the 10 db.

Estimates of the source noise reduction capabilities of S.A.M. and refan retrofitting for JT8D powered aircraft can be made using Reference 12. The reductions listed are those calculated at the FAR part 36 monitoring sites; 3.5 nautical miles from the start of the takeoff roll for takeoff, and one nautical mile from the landing threshold for approach. If we then make the rough approximations that S.A.M. and refan reduce noise levels by the same amount at all points in the flight path for each JT8D aircraft, Figures 8 - 17 show the improvements in annoyance and contour area due to these retrofits at San Jose. Taking the S.A.M. reductions to be 2 db on takeoff and 5 db on approach, improvements in contour area and annoyance are about 27% . Similarly, assuming refan reduces both takeoff and approach noise by 8 db*, the above improvements are about 64%.

All the aircraft in Table 1 were then replaced on a plane per plane basis by high bypass ratio trijets such as the DC-10 or L-1011, and by Douglas' drawing board advanced technology twin, the DC-X-200 (Reference 13). The DC-10 type operational profiles are shown in Table 5, and those for the DC-X-200 are assumed to be the same for the same range. These profiles show very high climb angles, due to the short

*Reference 16 shows results of recently concluded flight tests of refanned DC-9 aircraft, listing a takeoff noise level reduced by 8.2 db and an approach noise level reduced by 8.7 db.

range (San Jose - Southern California) nature and resulting light takeoff gross weights of the majority of the flights. The DC-X-200 was assumed to be 3 db quieter than the DC-10 on takeoff, and 1 db quieter on approach, as given in Reference 13. These improvements over the relatively quiet DC-10 are due to (1) two engines instead of three emitting less acoustic energy, (2) the proposed introduction of the higher aspect ratio supercritical wing, producing less drag and a lower aircraft weight and (3) the higher climb angle that a two-engine aircraft has relative to a trijet.

Tables 13 through 16 summarize the results of the DC-10 and DC-X-200, along with S.A.M., refan, and operational procedures. The introduction of the DC-10 reduces community annoyance by 52.2% in the 100% north case, and by 55.4 % for the 85%/15% split. Using a two-segment approach and cutting back thrust on takeoff, these improvements are increased to 67.5 % and 72.7% , respectively. The improvements in people exposed are substantially smaller, again due to the way the census data was input. The reduction in the area of the L_{DN} = 65 contour is nearly 80% for all 4 DC-10 cases. These large improvements are somewhat conservative, for if DC-10-10's flew into San Jose, the increased capacity of the DC-10, about twice that of the 727, would also allow a decrease in flight frequency.

The introduction of the DC-X-200 further reduces the noise problem. Community noise exposure is reduced by about 53 to 65%, and combined with a thrust cutback and two-segment approach, about 71 to 80%. Annoyance is reduced by 67% to 80%, and the L_{DN} = 65 contour is only 12% as large as in the standard case, a reduction of 88%. Finally, it is encouraging to note that introducing the DC-X-200 using two-segment approaches and thrust

cutbacks, only about 9 - 22% of the people presently annoyed would remain so. These DC-X-200 improvements are somewhat conservative also, since the passenger capacity of the aircraft is about 50% greater than that of a 727.

The benefits of all the above methods of reducing noise impact are summarized in Figure 18, for the constant population density, two-directional operations configuration.

LAND USE CONVERSION

A tabulation using 1975 assessment information showed that 1950 homes and 3 schools, with a total market value of $49,000,000, exist within today's San Jose noise impact boundary (see Figure 1). Taking into account the probable gap between the assessor's market values and today's potential market values, plus the cost of finding new homes and resettling the (10,000?) people within the noise impact boundary, one concludes that the cost of converting this property to a non-residential use is well over $65,000,000. The other alternative, acoustic insulation of these homes, would cost about $10 million, based on a cost per home of $4820* times 1950 homes plus 3 schools. No estimate is made here of the money that could be recovered over a period of time by reselling the land for noise compatible uses.

Tables 13 and 14 may be used to give the approximate cost reductions for land use conversion after the implementation of alternate operational procedures or improved technology. One should be careful not to include the airport area, about 1.5 square miles, or about 20% of the present L_{DN} = 65 contour area in any cost reduction estimates. With this in mind, we see that the introduction of the DC-10, and to an even greater degree, the DC-X-200, do essentially eliminate the need for any land use conversion, reducing the "noise impact area" by at least 77%, with the remaining land largely within the airport bounds. A second word of caution is that the figures given above are a good estimate of the

*Reference 11 refers to three "degrees" of soundproofing, only one of which (Stage 2) is effective at a reasonable cost. The cost of Stage 2 soundproofing is used above.

magnitude of the cost of buying up the residential homes, land and schools within the noise impact boundary; but due to the variability of the contour, and the fact that it is subject to movement with operational changes, these figures are only approximations.

There are a few problems and loopholes (aside from cost) with land use conversion:

a) What happens to homes that are built outside the present noise impact boundary, but after future airport growth, are enclosed within it?

b) Conversely, what happens to purchased land that due to improved technology and operational changes is no longer impacted in the future?

c) Acoustic insulation of homes does not reduce outdoor noise levels.

d) A discrepancy exists between homes inside the noise impact boundary that have been purchased or soundproofed, and those across the street, exposed to a Day-Night Level just below 65 -- and, under California law, not impacted.

e) A possible solution is the establishment of a buffer zone outside the noise impact boundary, where people can choose between having their homes purchased, soundproofed or to have nothing done. However, this too is subject to movement of the noise impact boundary.

CONCLUSIONS, COMMENTS AND RECOMMENDATIONS

1) Talks with airport officials indicate that the 85%/15% split is more representative of the airport operations throughout the year. This operational configuration is also slightly noisier than 100% northerly operations.

2) If money is to be spent on improved technology, (S.A.M. or refan), it is most beneficially spent on technology to reduce takeoff noise. This conclusion is at first surprising, with most of the affected people around San Jose apparently living under the approach path. However, Figures 8-17 clearly show that even a small takeoff noise reduction gives more improvement than an approach reduction. If this is the case at San Jose, where, at first glance, approach is the major problem, it is probably true for most airports. This is a strong argument in favor of refan as opposed to S.A.M.

3) The replacement of all operations by the DC-10/L-1011 class of aircraft at San Jose would cut community annoyance by over 50%, and in conjunction with cutbacks and two-segment approaches, by around 70%. Thus by using today's technology and implementing alternate operational procedures, San Jose's noise problem can be substantially relieved.

4) The introduction of an advanced technology twin such as the proposed DC-X-200 would all but eliminate community noise impact at San Jose.

5) Cutting back thrust on takeoff can give substantial reductions in noise impact. Overall, similar to (2), it appears that takeoff

noise reduction should be stressed.

6) The above contentions are further strengthened for the San Jose community by the growth north of the airport. This is in contrast with downtown San Jose, where there is really no room for residential growth.

7) While the benefits of the two-segment approach were smaller than those of thrust cutback, the improvement is still desirable.

8) Extrapolating the costs of land use conversion for San Jose (page 17) to the entire United States results in estimates well into the tens of billions of dollars for buying up residential property, and into the billions for acoustic insulation of homes. While this is only an estimate, we suspect it is conservative. The cost of S.A.M. or refan for the entire U.S. fleet is high also, but compared to the cost of land use conversion as a solution to the problem, S.A.M. or refan is probably a bargain.

9) Government subsidy, particularly for implementing refan, would reduce the San Jose airport noise problem by about 50%. Perhaps it is worth the estimated $2.2 billion price.

It should be noted that many of the results of this study may be generalized for airports with operations similar to San Jose's, i.e., short-range, JT8D powered aircraft (727, 737, DC-9). They may not, however, be generalized to airports with substantial long-range JT3D and JT9D (707, DC-8, 747) operations without considerable modification.

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16. DC-9 Flight Demonstration Program With Refanned JT8D Engines. Final Report, Vol. 1, Douglas Aircraft Company, NASA CR-134857.

SAN JOSE MUNICIPAL AIRPORT

September 1974, Daily Operations

AIRCRAFT	APPROACH			TAKEOFF		
	DAYTIME 0700-2200	NIGHT 2200-0700	EQUIVALENT* TOTAL	DAYTIME 0700-2200	NIGHT 2200-0700	EQUIVALENT* TOTAL
727	27.73	3.78	65.5	27.73	3.78	65.5
737	19.45	0.81	27.55	19.45	0.81	27.55
DC-9	10.35	--	10.35	10.35	--	10.35
707	1.35	--	1.35	1.35	--	1.35
DC-8	0.85	--	0.85	0.85	--	0.85

*Equivalent Total = (N_{DAY} + 10 N_{NIGHT}), from the Definition of L_{DN}.

TABLE 1

TAKEOFF FLIGHT PROFILES

	SEGMENT LENGTH IN FT (HORIZONTAL DISTANCE)	FLIGHT PATH ANGLE IN DEGREES (WITH GROUND)	THRUST PER ENGINE (F_N/δ) IN LBS	RADIUS OF TURN (0.=STRAIGHT)	AVERAGE SEGMENT VELOCITY (KNOTS)
	6000.	0.00	12300.	0.	100.
	2000.	3.95	12300.	0.	165.
727-200	11000.	7.13	12300.	0.	165.
165,000 lb	14500.	5.82	10700.	0.	165.
	30000.	3.79	10700.	0.	250.
	200000.	7.56	10230.	0.	250.
	4100.	0.00	12300.	0.	100.
	2400.	4.90	12300.	0.	157.
727-200	7500.	10.00	12300.	0.	157.
140,000 lb	11000.	7.76	10700.	0.	157.
	31100.	4.49	10700.	0.	250.
	200000.	9.46	10230.	0.	250.
	3700.	0.00	12200.	0.	100.
	2300.	8.21	12200.	0.	150.
DC-9-32	7500.	8.97	12200.	0.	150.
89,000 lb	11500.	8.13	10800.	0.	150.
	35000.	4.79	10800.	0.	250.
	200000.	7.76	10600.	0.	250.
	3700.	0.00	12500.	0.	100.
	2000.	6.31	12500.	0.	167.
737-200	6000.	11.02	12500.	0.	167.
91,000 lb	10000.	8.70	10750.	0.	167.
	9000.	3.37	10750.	0.	250.
	200000.	6.18	10300.	0.	250.
	8200.	0.00	15200.	0.	104.
	4000.	3.00	15200.	0.	176.
DC-8-61	15000.	5.00	15200.	0.	176.
M.T.O.G.W.	21000.	4.00	12600.	0.	176.
	26750.	1.00	12600.	0.	213.
	200000.	3.00	12300.	0.	250.
	8200.	0.00	15200.	0.	104.
	4000.	3.00	15200.	0.	176.
707-320	15000.	5.00	15200.	0.	176.
M.T.O.G.W.	21000.	4.00	12600.	0.	176.
	26750.	1.00	12600.	0.	213.
	200000.	3.00	12300.	0.	250.

TABLE 2

APPROACH FLIGHT PROFILES

	SEGMENT LENGTH IN FT (HORIZONTAL DISTANCE)	FLIGHT PATH ANGLE IN DEGREES (WITH GROUND)	THRUST PER ENGINE (F_N/δ) IN LBS	RADIUS OF TURN (0.=STRAIGHT)	AVERAGE SEGMENT VELOCITY (KNOTS)
		Standard Approach			
DC-8-61	5970.	0.00	5208.	0.	100.
	200000.	3.00	5208.	0.	154.
707-320	5970.	0.00	5208.	0.	100.
	200000.	3.00	5208.	0.	154.
727-200	4800.	0.00	4330.	0.	100.
	200000.	3.00	4330.	0.	145.
737-200	3750.	0.00	3660.	0.	100.
	200000.	3.00	3660.	0.	146.
DC-9-32	4920.	0.00	5411.	0.	100.
	200000.	3.00	5411.	0.	141.
		Two Segment Approach			
DC-8-61	5970.	0.00	5208.	0.	100.
	15265.	3.00	5208.	0.	154.
	200000.	6.00	2600.	0.	154.
707-320	5970.	0.00	5208.	0.	100.
	15265.	3.00	5208.	0.	154.
	200000.	6.00	2600.	0.	159.
727-200	4800.	0.00	4330.	0.	100.
	15265.	3.00	4330.	0.	145.
	200000.	6.00	1800.	0.	150.
737-200	3750.	0.00	3660.	0.	100.
	15265.	3.00	3660.	0.	146.
	200000.	6.00	2100.	0.	151.
DC-9-32	4920.	0.00	5411.	0.	100.
	15265.	3.00	5411.	0.	141.
	200000.	6.00	2800.	0.	148.

TABLE 3

CUTBACK TAKEOFF PROFILES

	SEGMENT LENGTH IN FT (HORIZONTAL DISTANCE)	FLIGHT PATH ANGLE IN DEGREES (WITH GROUND)	THRUST PER ENGINE (F_N/δ) IN LBS	RADIUS OF TURN (0.=STRAIGHT)	AVERAGE SEGMENT VELOCITY (KNOTS)
	6000.	0.00	12300.	0.	100.
	2000.	3.95	12300.	0.	165.
727-200	11000.	7.13	12300.	0.	165.
165,000 lb	5057.	2.25	8060.	0.	177.
	33500.	2.66	8200.	0.	179.
	200000.	2.70	8610.	0.	183.
	4100.	0.00	12300.	0.	100.
727-200	2400.	4.90	12300.	0.	157.
140,000 lb	7500.	10.00	12300.	0.	157.
	200000.	3.60	8200.	0.	180.
	3700.	0.00	12200.	0.	100.
DC-9-32	2300.	8.21	12200.	0.	150.
89,000 lb	7500.	8.97	12200.	0.	150.
	200000.	5.50	9600.	0.	180.
	3700.	0.00	12500.	0.	100.
	2000.	6.31	12500.	0.	167.
737-200	6500	11.02	12500.	0.	167.
91,000 lb	11757.	4.33	8570.	0.	168.
	13000.	4.14	8800.	0.	170.
	200000.	4.24	9090.	0.	173.
	8200.	0.00	15200.	0.	104.
DC-8-61	4000.	3.00	15200.	0.	176.
M.T.O.G.W.	15000.	5.00	15200.	0.	176.
	200000.	2.29	11000.	0.	178.
	8200.	0.00	15200.	0.	104.
707-320	4000.	3.00	15200.	0.	176.
M.T.O.G.W.	15000.	5.00	15200.	0.	176.
	200000.	2.29	11000.	0.	178.

TABLE 4

DC-10-10 FLIGHT PROFILES

DC-X-200 Medium Range Twin Engine Advanced Aircraft Assumed To Have Same Flight Path As DC-10-10 For Same Range*

	SEGMENT LENGTH IN FT (HORIZONTAL DISTANCE)	FLIGHT PATH ANGLE IN DEGREES (WITH GROUND)	THRUST PER ENGINE (F_N/δ) IN LBS	RADIUS OF TURN (0.=STRAIGHT)	AVERAGE SEGMENT VELOCITY (KNOTS)
	3500.	0.00	35300.	0.	104.
	6500.	12.99	31000.	0.	158.
STANDARD	8500.	10.00	31000.	0.	176.
TAKEOFF	11500.	6.70	27400.	0.	213.
300,000 LB	24500.	4.20	27400.	0.	250.
300 N.MI.	200000.	7.20	27400.	0.	250.
	4500.	0.00	35300.	0.	104.
STANDARD	9000.	9.46	31000.	0.	158.
TAKEOFF	11500.	7.43	31000.	0.	176.
340,000 LB	34000.	4.04	27400.	0.	213.
1500 N.MI.	200000.	5.71	27400.	0.	250.
	5500.	0.00	35300.	0.	104.
STANDARD	11500.	7.43	31000.	0.	158.
TAKEOFF	14500.	5.91	31000.	0.	176.
375,000 LB	31000.	3.23	27400.	0.	213.
2400 N.MI.	200000.	3.97	27400.	0.	250.
CUTBACK					
TAKEOFF	3500.	0.00	35300.	0.	104.
300,000 LB	6500.	12.99	31000.	0.	158.
300 N.MI.	200000.	3.66	17700.	0.	250.
CUTBACK					
TAKEOFF	4000.	0.00	35300.	0.	104.
340,000 LB	9000.	9.46	31000.	0.	158.
1500 N.MI.	200000.	3.50	20400.	0.	250.
CUTBACK					
TAKEOFF	5500.	0.00	35300.	0.	104.
375,000 LB	11500.	7.43	31000.	0.	158.
2400 N.MI.	200000.	3.44	22650.	0.	250.
STANDARD	3800.	0.00	7814.	0.	100.
APPROACH	200000.	3.00	7814.	0.	140.
	3800.	0.00	7814.	0.	100.
TWO SEGMENT	15265.	3.00	7814.	0.	140.
APPROACH	200000.	6.00	3583.	0.	152.

*See pp. 14 and 15

TABLE 5

CORRELATION OF CALCULATED WITH MEASURED
L_{DN} VALUES AT SAN JOSE MONITOR POINTS

	MEASURED VALUES		CALCULATED VALUES		$\left(L_{DN_{CALCULATED}} - CNEL_{MEASURED}\right)$	
SITE	SEPT., '74	DEC., '74	100% NORTH	85% NORTH 15% SOUTH	100% NORTH SEPT., '74	85% NORTH 15% SOUTH DEC., '74
1	61.4	62.8	62.7	63.1	1.3	0.3
2	68.4	70.1	66.7	67.4	-1.7	-2.7
3	78.4	78.7	77.9	79.0	-0.5	0.3
4	54.1		53.1	54.3	-1.0	
5	62.3	67.5	64.9	66.2	2.6	-1.3
6	60.7	66.4	62.6	63.6	1.9	-2.8
7	76.1	76.0	74.6	74.2	-1.5	-1.8
8	68.9	70.0	69.9	69.5	1.0	-0.5

TABLE 6

RESULTS OF ALTERNATE OPERATIONAL PROCEDURES AT SAN JOSE
OPERATIONS: 100% NORTH (RUNWAY 30L)

PROCEDURE (RUNWAY)	Contour* Areas, sq. mi. L_{DN} = 46	L_{DN} = 55	L_{DN} = 65	L_{DN} = 70	PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	% IMPROVEMENT OVER STANDARD PROCEDURES IN: PEOPLE EXPOSED	% IMPROVEMENT OVER STANDARD PROCEDURES IN: PEOPLE HIGHLY ANNOYED
STANDARD TAKEOFF (30L) AND APPROACH (30L)	125.5	36.3	7.27	3.21	140,490	20,873		
CUTBACK TAKEOFF, (30L) STANDARD APPROACH (30L)	126.7	30.3	6.09	2.93	131,854	19,728	6.2	5.6
STANDARD TAKEOFF, (30L) TWO SEGMENT APPROACH (30L)	108.2	33.3	7.22	3.21	114,714	17,885	18.4	14.4
CUTBACK TAKEOFF, (30L) TWO SEGMENT APPROACH (30L)	109.9	27.3	6.04	2.93	106,078	16,740	24.5	19.9
STANDARD TAKEOFF, (30L) STANDARD APPROACH (30L) BASE LEG FROM WEST	125.5	36.3	7.27	3.21	141,302	20,572	-0.6	1.6
STANDARD TAKEOFF, (30L) STANDARD APPROACH (30L) BASE LEG FROM EAST	125.5	36.3	7.27	3.21	132,366	21,499	5.8	-2.9

TABLE 7

*These areas reflect combined takeoff and landing effects.

RESULTS OF ALTERNATE OPERATIONAL PROCEDURES AT SAN JOSE
OPERATIONS: 85% NORTH (RUNWAY 30L)/15% SOUTH (RUNWAY 12R)

PROCEDURE	Contour* Areas, sq. mi. L_{DN} = 46	55	65	70	PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	% IMPROVEMENT OVER STANDARD PROCEDURES IN: PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED
STANDARD TAKEOFF AND APPROACH (30L and 12R)	131.11	37.03	7.32	3.21	175,991	26,139		
CUTBACK TAKEOFF, STANDARD APPROACH (30L and 12R)	128.9	30.12	6.16	2.96	149,558	21,990	15.0	15.9
STANDARD TAKEOFF, TWO SEGMENT APPROACH (30L and 12R)	118.0	33.74	7.17	3.21	175,991	23,933	00.0	8.4
CUTBACK TAKEOFF, TWO SEGMENT APPROACH (30L and 12R)	114.1	26.66	6.04	2.96	131,854	19,703	25.1	24.6

*These areas reflect combined takeoff and landing effects

TABLE 8

RESULTS OF ALTERNATE OPERATIONAL PROCEDURES ON A CONSTANT POPULATION DENSITY
UNIDIRECTIONAL OPERATIONS

PROCEDURE	Contour* Areas, sq. mi. L_{DN} = 46	55	65	70	PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	% IMPROVEMENT OVER STANDARD PROCEDURES IN: PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED
STANDARD TAKEOFF AND APPROACH	125.5	36.3	7.27	3.21	1,008,857	115,895		
CUTBACK TAKEOFF, STANDARD APPROACH	126.7	30.3	6.09	2.93	1,017,418	105,152	-0.9	9.3
STANDARD TAKEOFF, TWO SEGMENT APPROACH	108.2	33.3	7.22	3.21	865,007	103,287	14.3	10.9
CUTBACK TAKEOFF, TWO SEGMENT APPROACH	109.9	27.3	6.04	2.93	881,953	92,930	12.6	19.8

*These areas reflect combined takeoff and landing effects.

TABLE 9

RESULTS OF ALTERNATE OPERATIONAL PROCEDURES
ON A CONSTANT POPULATION DENSITY,
TWO DIRECTIONAL MIX, 85%/15%

PROCEDURE	Contour* Areas, sq. mi. L_{DN} = 46 / 65	Contour* Areas, sq. mi. L_{DN} = 55 / 70	PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	% IMPROVEMENT OVER STANDARD PROCEDURES IN: PEOPLE EXPOSED	% IMPROVEMENT OVER STANDARD PROCEDURES IN: PEOPLE HIGHLY ANNOYED
STANDARD TAKEOFF AND APPROACH (BOTH DIRECTIONS)	131.1 / 7.32	37.03 / 3.21	1,051,915	119,752		
CUTBACK TAKEOFF, STANDARD APPROACH (BOTH DIRECTIONS)	128.9 / 6.16	30.10 / 2.96	1,035,298	105,909	1.6	11.6
STANDARD TAKEOFF, TWO SEGMENT APPROACH (BOTH DIRECTIONS)	118.0 / 7.17	33.74 / 3.21	943,014	108,784	10.4	9.2
CUTBACK TAKEOFF, TWO SEGMENT APPROACH (BOTH DIRECTIONS)	114.1 / 6.04	26.66 / 2.96	915,283	93,305	13.0	22.1

*These areas reflect combined takeoff and landing effects.

TABLE 10

CONTOUR AREA AND ANNOYANCE REDUCTIONS DUE TO
PROPOSED IMPROVED TECHNOLOGY AT SAN JOSE
OPERATIONS: 100% NORTH (RUNWAY 30L)

TAKEOFF NOISE REDUCTION, (dB)	APPROACH NOISE REDUCTION, (dB)	$A^{*}_{CONTOUR}$ / $A_{STANDARD\ CONTOUR}$	CENSUS DATA $P^{**}_{EXPOSED}$ / $P_{EXPOSED\ STANDARD}$	P^{**}_{HA} / $P_{HA\ STANDARD}$
0	0	STANDARD CASE		
2	0	.80	.94	.86
5	0	.58	.80	.71
8	0	.45	.71	.60
12	0	.35	.65	.52
0	2	.96	1.00	.92
2	2	.76	.94	.78
5	2	.55	.77	.62
8	2	.41	.68	.51
12	2	.31	.59	.43
0	5	.93	.87	.84
2	5	.73	.84	.69
5	5	.51	.63	.53
8	5	.38	.51	.42
12	5	.28	.45	.33
0	8	.92	.75	.79
2	8	.71	.69	.64
5	8	.50	.52	.48
8	8	.36	.42	.37
12	8	.25	.35	.28
0	12	.91	.75	.76
2	12	.71	.68	.62
5	12	.49	.52	.45
8	12	.35	.42	.34
12	12	.25	.31	.25

*These ratios are the average of the L_{DN} = 46,55,65 and 70 contour ratios

**P represents people, P_{HA} represents people highly annoyed

TABLE 11

CONTOUR AREA AND ANNOYANCE REDUCTIONS DUE TO
PROPOSED IMPROVED TECHNOLOGY AT SAN JOSE
OPERATIONS: 85% NORTH (RUNWAY 30L)/15% SOUTH (RUNWAY 12R)

TAKEOFF NOISE REDUCTION, (dB)	APPROACH NOISE REDUCTION, (dB)	$A^*_{CONTOUR}$ / $A_{STANDARD\ CONTOUR}$	CENSUS DATA: $P^{**}_{EXPOSED}$ / $P_{EXPOSED\ STANDARD}$	CENSUS DATA: P^{**}_{HA} / $P_{HA\ STANDARD}$
0	0	STANDARD CASE		
2	0	.79	.92	.83
5	0	.57	.75	.64
8	0	.44	.57	.52
12	0	.34	.52	.43
0	2	.97	1.00	.96
2	2	.76	.87	.78
5	2	.54	.68	.59
8	2	.40	.57	.47
12	2	.31	.52	.37
0	5	.95	1.00	.92
2	5	.74	.85	.74
5	5	.51	.68	.54
8	5	.37	.53	.41
12	5	.27	.44	.31
0	8	.93	1.00	.90
2	8	.72	.81	.71
5	8	.49	.64	.51
8	8	.36	.52	.37
12	8	.25	.43	.27
0	12	.92	.96	.89
2	12	.71	.81	.69
5	12	.48	.64	.49
8	12	.34	.45	.35
12	12	.24	.32	.25

*These ratios are the average of the L_{DN} = 46,55,65 and 70 contour ratios

**P represents people, P_{HA} represents people highly annoyed

TABLE 12

SUMMARY - RESULTS OF ALTERNATE OPERATIONAL PROCEDURES AND IMPROVED TECHNOLOGY AT SAN JOSE
OPERATIONS: 100% NORTH (RUNWAY 30L)

PROCEDURE AND TECHNOLOGY	PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	% IMPROVEMENT OVER STANDARD PROCEDURES IN: PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	AREA OF L_{DN} = 65 CONTOUR
STANDARD TAKEOFF AND APPROACH, TODAY'S AIRCRAFT	140,490	20,873	STANDARD CASE		
CUTBACK TAKEOFF, TWO SEGMENT APPROACH, TODAY'S AIRCRAFT	106,078	16,740	24.5	19.9	17.0
STANDARD TAKEOFF AND APPROACH S.A.M. JT8D*	118,016	14,469	16.0	30.7	27.4
STANDARD TAKEOFF AND APPROACH REFAN JT8D*	59,575	7,755	57.6	62.9	66.5
CUTBACK TAKEOFF TWO SEGMENT APPROACH. S.A.M. JT8D*	90,391	12,475	36.7	40.2	38.1
CUTBACK TAKEOFF TWO SEGMENT APPROACH REFAN JT8D*	52,851	6,656	63.4	68.1	68.5
STANDARD TAKEOFF AND APPROACH ALL DC-10-10 OPERATIONS	102,981	9,973	26.7	52.2	77.0
STANDARD TAKEOFF AND APPROACH ALL DC-X-200 OPERATIONS	65,315	6,964	53.5	66.6	87.8
CUTBACK TAKEOFF TWO SEGMENT APPROACH ALL DC-10-10 OPERATIONS	66,635	6,780	52.6	67.5	80.5
CUTBACK TAKEOFF TWO SEGMENT APPROACH ALL DC-X-200 OPERATIONS	40,165	4,650	71.4	77.7	88.0

*See p. 14

TABLE 13

SUMMARY - RESULTS OF ALTERNATE OPERATIONAL PROCEDURES AND IMPROVED TECHNOLOGY AT SAN JOSE
OPERATIONS: 85% NORTH (RUNWAY 30L)/15% SOUTH (RUNWAY 12R)

PROCEDURE (BOTH DIRECTIONS) AND TECHNOLOGY	PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	% IMPROVEMENT OVER STANDARD PROCEDURES IN:		
			PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	AREA OF $L_{DN} = 65$ CONTOUR
STANDARD TAKEOFF AND APPROACH, TODAY'S AIRCRAFT	175,991	26,139	STANDARD CASE		
CUTBACK TAKEOFF, TWO SEGMENT APPROACH, TODAY'S AIRCRAFT	131,854	19,703	25.1	24.6	17.5
STANDARD TAKEOFF AND APPROACH S.A.M. JT8D*	149,325	19,266	15.2	26.3	27.5
STANDARD TAKEOFF AND APPROACH REFAN JT8D*	90,843	9,725	48.2	62.8	66.9
CUTBACK TAKEOFF TWO SEGMENT APPROACH S.A.M. JT8D*	117,724	14,983	33.1	42.7	37.6
CUTBACK TAKEOFF TWO SEGMENT APPROACH REFAN JT8D*	68,944	7,859	60.8	69.9	68.4
STANDARD TAKEOFF AND APPROACH ALL DC-10-10 OPERATIONS	123,291	11,647	29.9	55.4	77.3
STANDARD TAKEOFF AND APPROACH ALL DC-X-200 OPERATIONS	82,245	7,492	53.3	71.3	87.4
CUTBACK TAKEOFF TWO SEGMENT APPROACH ALL DC-10-10 OPERATIONS	69,099	7,119	60.7	72.7	80.5
CUTBACK TAKEOFF TWO SEGMENT APPROACH ALL DC-X-200 OPERATIONS	42,659	4,608	75.8	82.4	88.0

*See p. 14

TABLE 14

SUMMARY - RESULTS OF ALTERNATE OPERATIONAL PROCEDURES AND IMPROVED TECHNOLOGY ON A CONSTANT POPULATION DENSITY UNIDIRECTIONAL OPERATIONS

PROCEDURE AND TECHNOLOGY	PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	% IMPROVEMENT OVER STANDARD PROCEDURES IN:		
			PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	AREA OF $L_{DN} = 65$ CONTOUR
STANDARD TAKEOFF AND APPROACH, TODAY'S AIRCRAFT	1,008,857	115,895	STANDARD CASE		
CUTBACK TAKEOFF, TWO SEGMENT APPROACH, TODAY'S AIRCRAFT	881,953	92,930	12.6	19.8	17.0
STANDARD TAKEOFF AND APPROACH S.A.M. JT8D*	741,862	82,588	26.5	28.7	27.4
STANDARD TAKEOFF AND APPROACH REFAN JT8D*	426,706	39,530	57.7	65.9	66.5
CUTBACK TAKEOFF TWO SEGMENT APPROACH S.A.M. JT8D*	671,018	67,672	33.5	41.6	38.1
CUTBACK TAKEOFF TWO SEGMENT APPROACH REFAN JT8D*	354,317	30,915	64.9	73.3	68.5
STANDARD TAKEOFF AND APPROACH ALL DC-10-10 OPERATIONS	571,459	45,004	43.4	61.2	77.0
STANDARD TAKEOFF AND APPROACH ALL DC-X-200 OPERATIONS	371,413	23,908	63.2	79.4	87.8
CUTBACK TAKEOFF TWO SEGMENT APPROACH ALL DC-10-10 OPERATIONS	356,682	25,090	64.6	78.4	80.5
CUTBACK TAKEOFF TWO SEGMENT APPROACH ALL DC-X-200 OPERATIONS	205,524	11,131	79.6	90.4	88.0

*See p. 14

TABLE 15

SUMMARY - RESULTS OF ALTERNATE OPERATIONAL PROCEDURES AND IMPROVED TECHNOLOGY ON A CONSTANT POPULATION DENSITY
TWO DIRECTIONAL MIX 85%/15%

PROCEDURE (BOTH DIRECTIONS) AND TECHNOLOGY	PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	% IMPROVEMENT OVER STANDARD PROCEDURES IN:		
			PEOPLE EXPOSED	PEOPLE HIGHLY ANNOYED	AREA OF L_{DN} = 65 CONTOUR
STANDARD TAKEOFF AND APPROACH, TODAY'S AIRCRAFT	1,051,915	119,752	STANDARD CASE		
CUTBACK TAKEOFF, TWO SEGMENT APPROACH, TODAY'S AIRCRAFT	915,285	93,305	13.0	22.1	17.5
STANDARD TAKEOFF AND APPROACH S.A.M. JT8D*	787,191	86,076	25.2	28.1	27.5
STANDARD TAKEOFF AND APPROACH REFAN JT8D*	443,943	40,400	57.8	66.3	66.8
CUTBACK TAKEOFF TWO SEGMENT APPROACH S.A.M. JT8D*	693,936	67,962	34.0	43.2	37.6
CUTBACK TAKEOFF TWO SEGMENT APPROACH REFAN JT8D*	356,034	30,609	66.2	74.4	68.4
STANDARD TAKEOFF AND APPROACH ALL DC-10-10 OPERATIONS	577,989	44,930	45.1	62.5	77.3
STANDARD TAKEOFF AND APPROACH ALL DC-X-200 OPERATIONS	371,458	23,784	64.7	80.1	87.4
CUTBACK TAKEOFF TWO SEGMENT APPROACH ALL DC-10-10 OPERATIONS	343,480	23,764	67.3	80.2	80.5
CUTBACK TAKEOFF TWO SEGMENT APPROACH ALL DC-X-200 OPERATIONS	196,863	10,510	81.3	91.2	88.0

*See p. 14

TABLE 16

--- 85% NORTH/15% SOUTH

— 100% NORTH

+ CENSUS TRACT CENTROID

⊕ REMOTE MONITORING SITE

SAN JOSE MUNICIPAL AIRPORT AND VICINITY

Figure 1

1970 SANTA CLARA COUNTY CENSUS TRACTS

Figure 2

DISTRIBUTION OF FLIGHTS BY RANGE FROM SAN JOSE

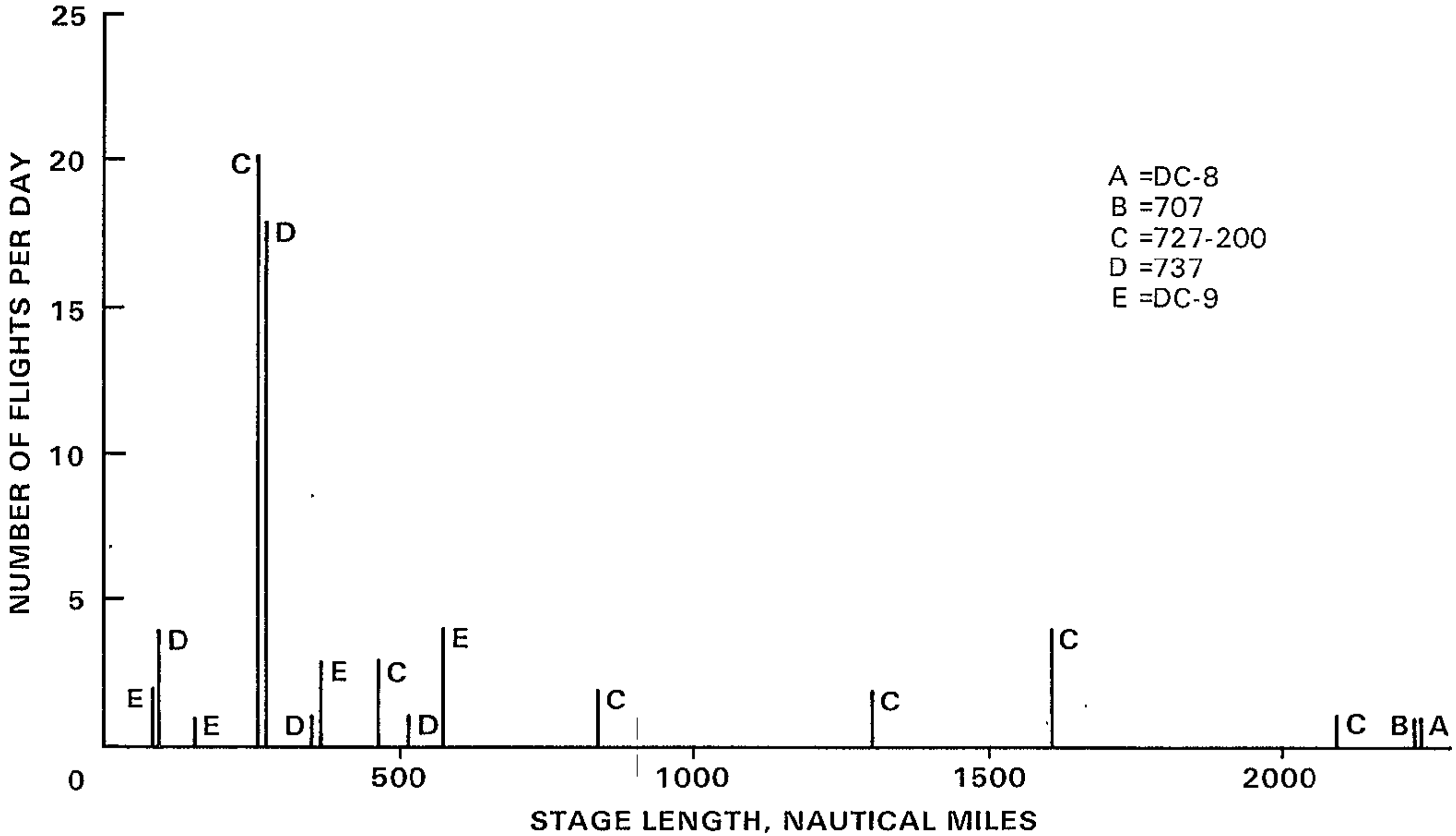
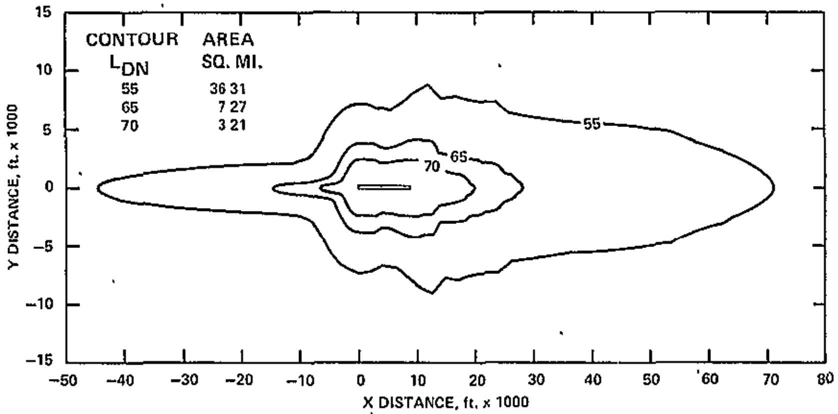
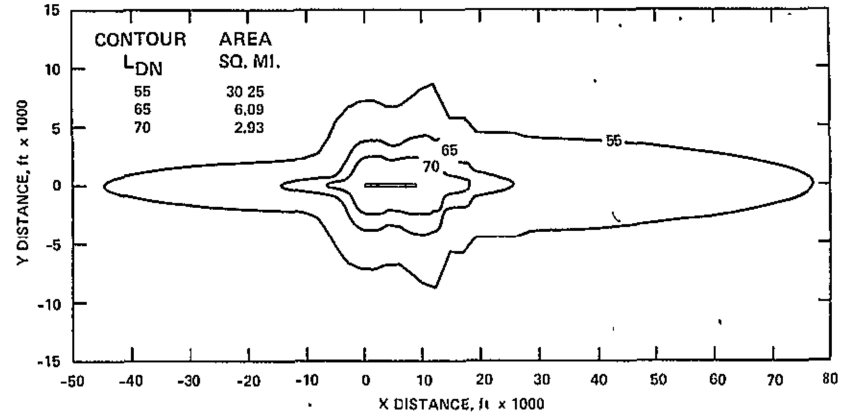


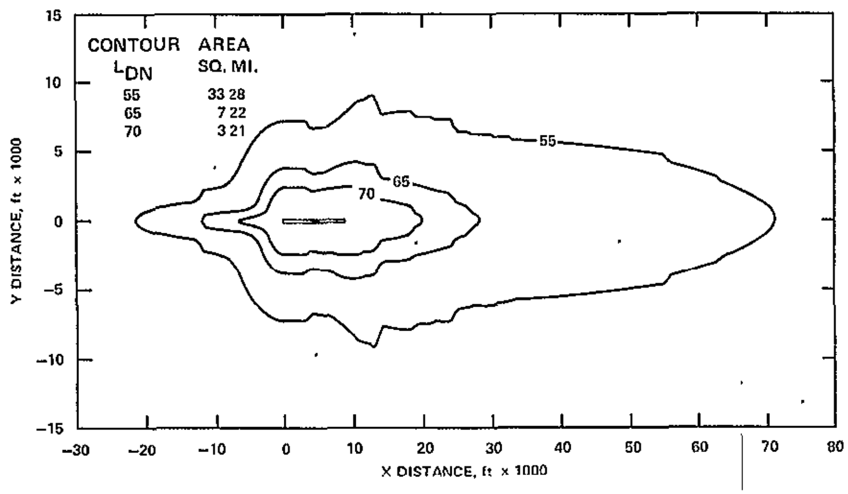
Figure 3



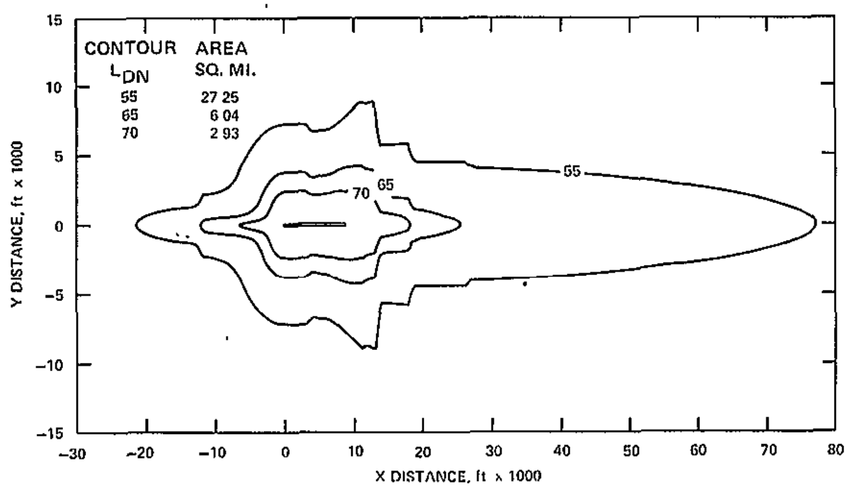
STANDARD TAKEOFF, STANDARD APPROACH



CUTBACK TAKEOFF, STANDARD APPROACH



STANDARD TAKEOFF, TWO-SEGMENT APPROACH

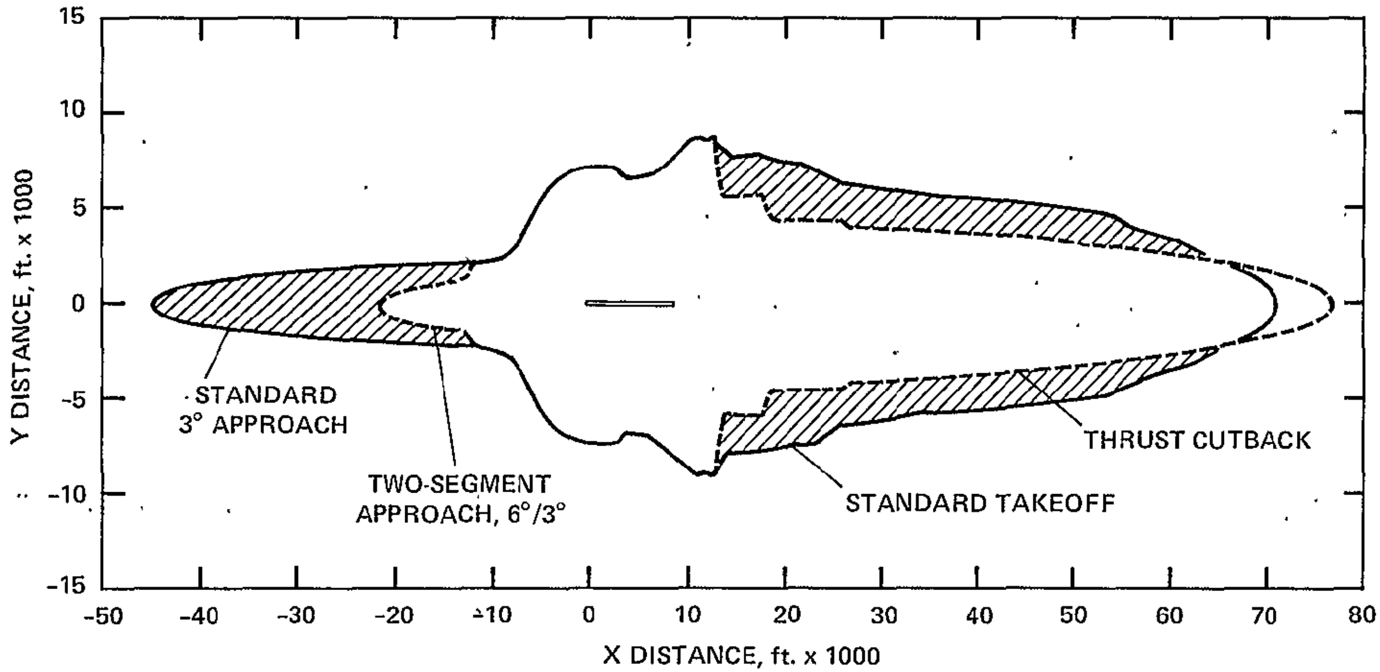


CUTBACK TAKEOFF, TWO-SEGMENT APPROACH

SAN JOSE L_{DN} CONTOURS

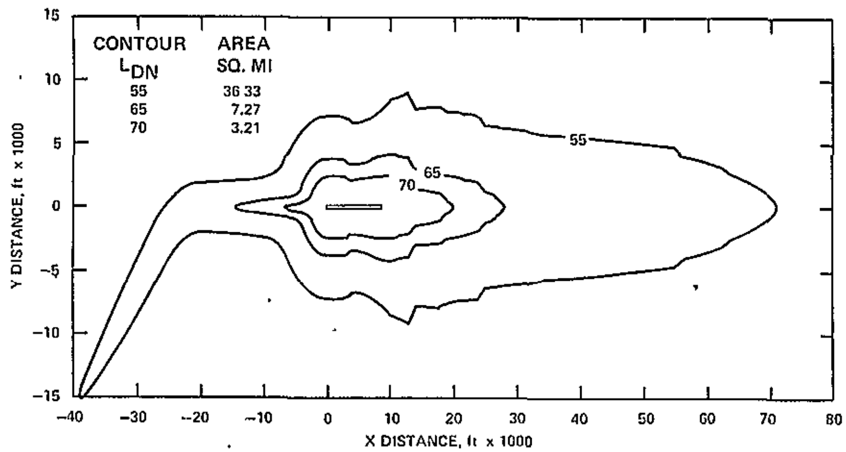
OPERATIONS: 100% NORTH (LEFT TO RIGHT)

Figure 4

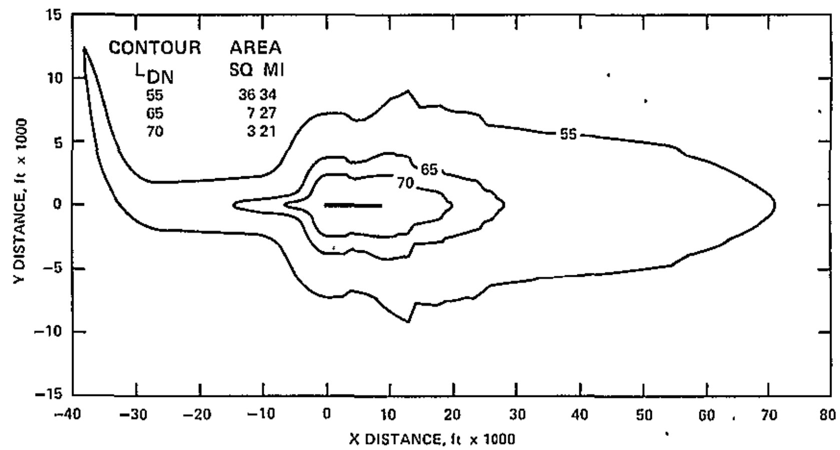


L_{DN} = 55 CONTOUR AREA REDUCTIONS DUE TO TWO SEGMENT APPROACHES AND THRUST CUTBACKS ON TAKEOFF

Figure 5



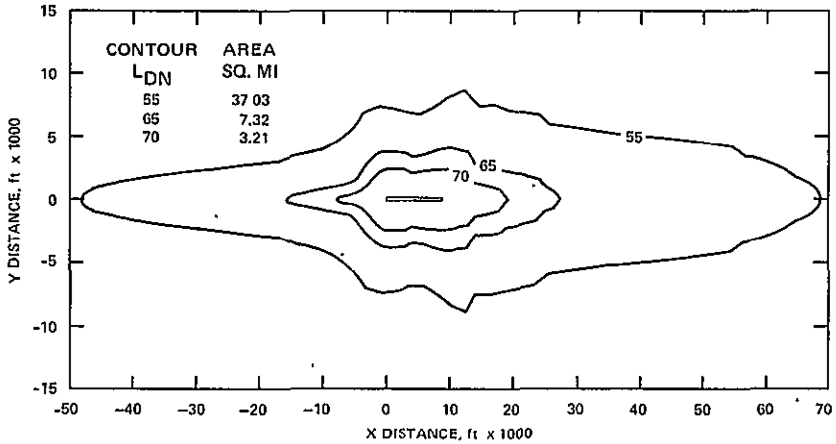
BASE LEG FROM EAST



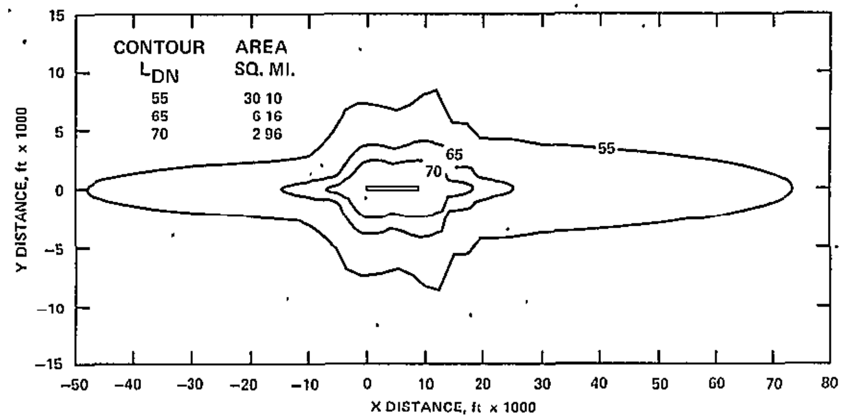
BASE LEG FROM WEST

MODIFIED APPROACH PATHS

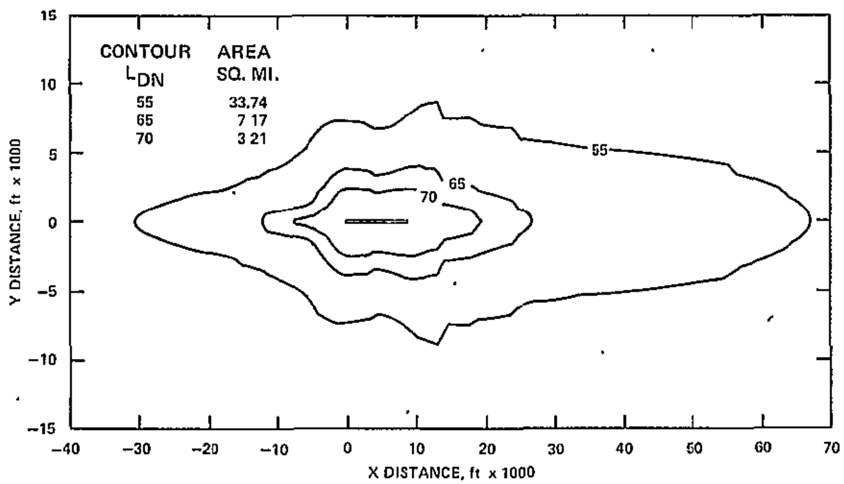
Figure 6



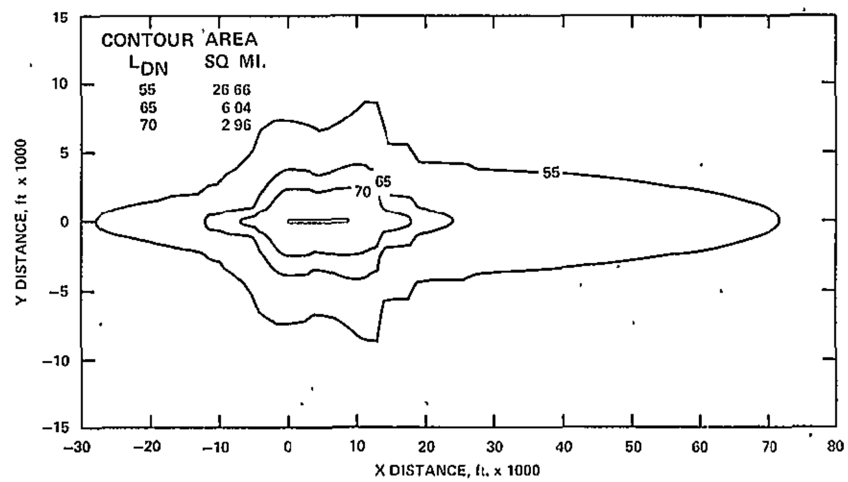
STANDARD TAKEOFF, STANDARD APPROACH



CUTBACK TAKEOFF, STANDARD APPROACH



STANDARD TAKEOFF, TWO-SEGMENT APPROACH



CUTBACK TAKEOFF, TWO-SEGMENT APPROACH

SAN JOSE L_{DN} CONTOURS

OPERATIONS: 85% NORTH (LEFT TO RIGHT), 15% SOUTH

Figure 7

CONTOUR AREA AND ANNOYANCE REDUCTIONS DUE TO IMPROVED TECHNOLOGY AT SJC

OPERATIONS: 100% NORTH

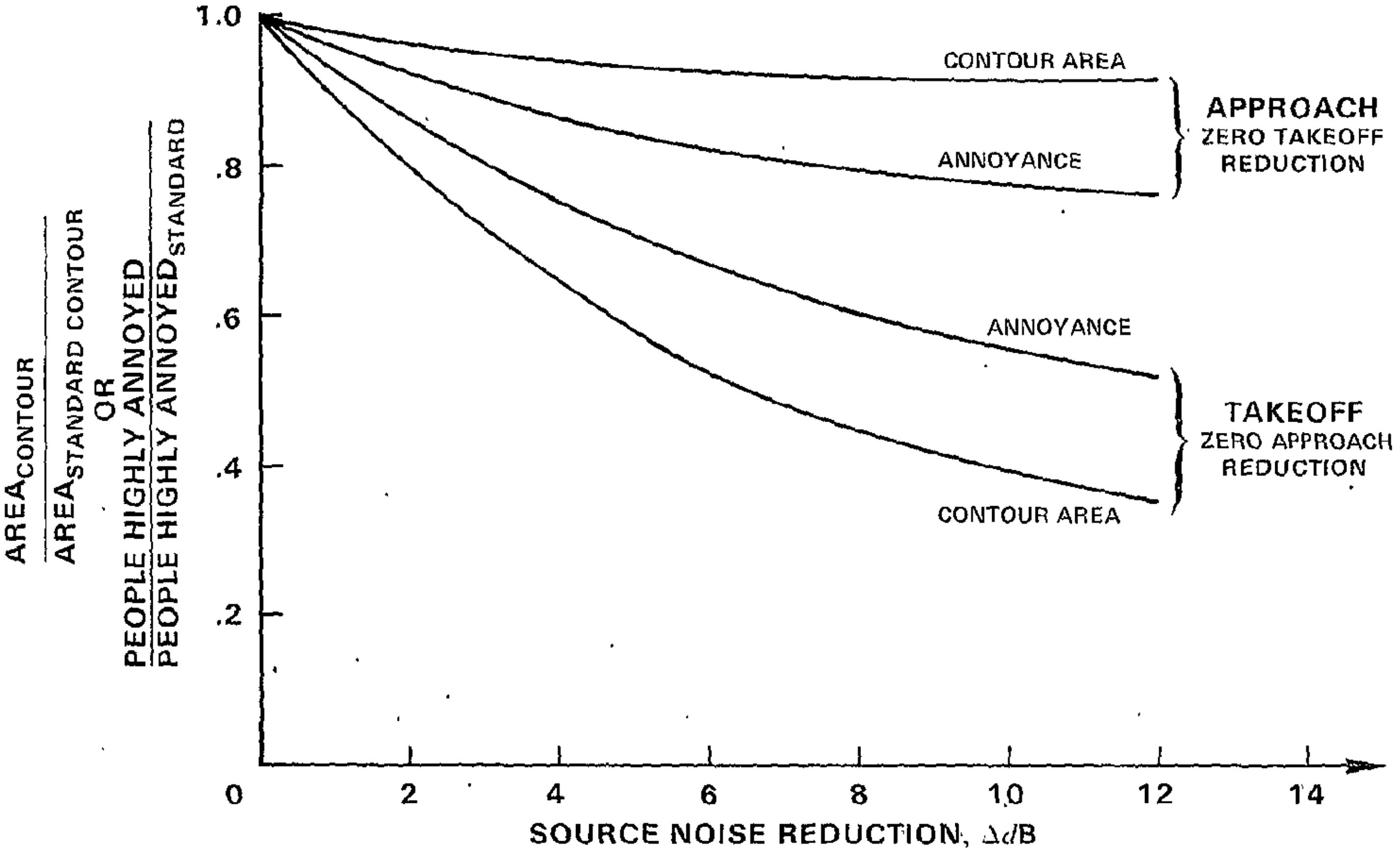
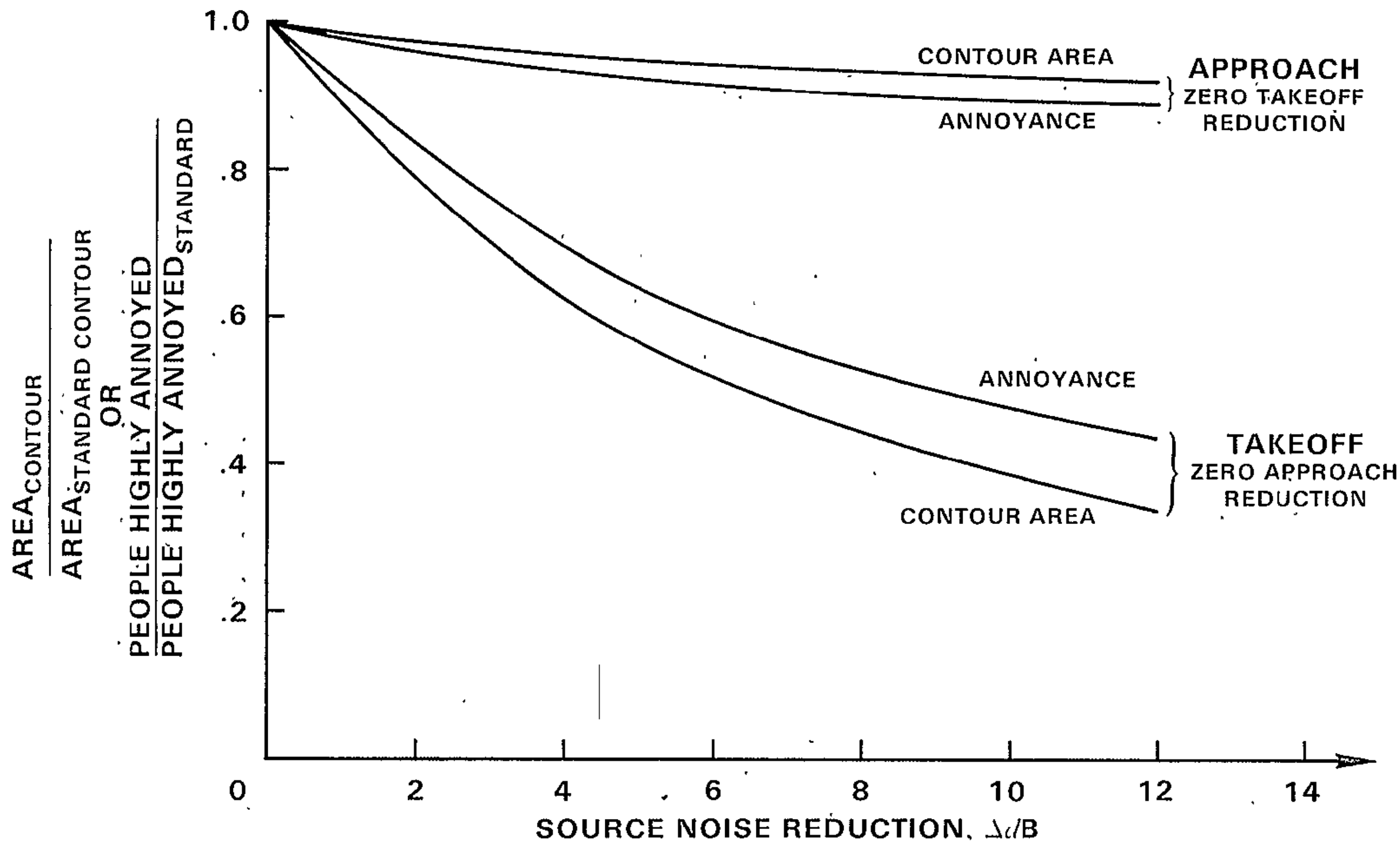


Figure 8

CONTOUR AREA AND ANNOYANCE REDUCTIONS DUE TO IMPROVED TECHNOLOGY AT SJC

OPERATIONS: 85% NORTH, 15% SOUTH



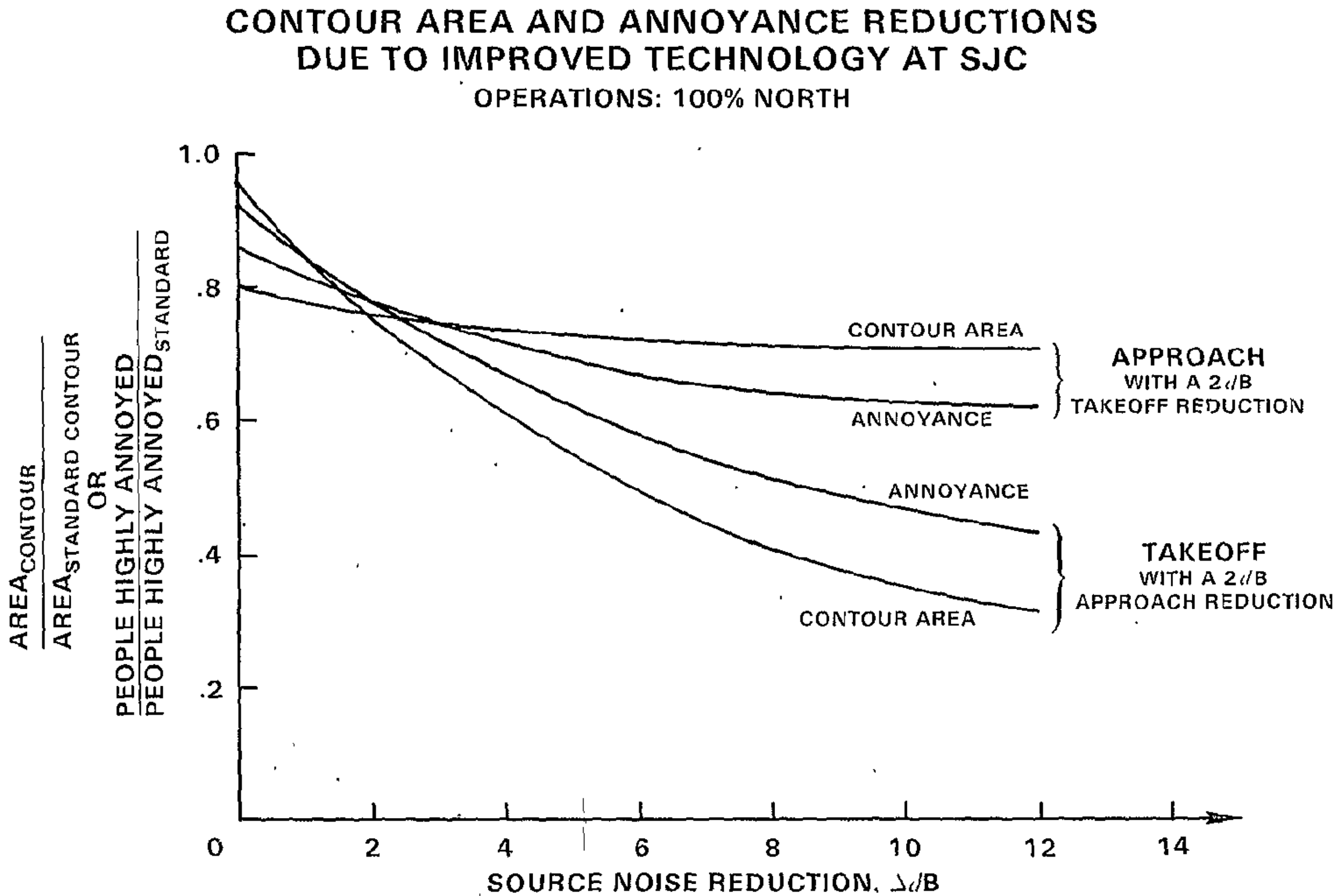

CONTOUR AREA AND ANNOYANCE REDUCTIONS
DUE TO IMPROVED TECHNOLOGY AT SJC
OPERATIONS: 100% NORTH
AREA CONTOUR / AREA STANDARD CONTOUR OR PEOPLE HIGHLY ANNOYED / PEOPLE HIGHLY ANNOYED STANDARD
1.0
.8
.6
.4
.2
0
2
4
6
8
10
12
14
SOURCE NOISE REDUCTION, ΔdB
CONTOUR AREA
ANNOYANCE
APPROACH
WITH A 2dB
TAKEOFF REDUCTION
ANNOYANCE
CONTOUR AREA
TAKEOFF
WITH A 2dB
APPROACH REDUCTION

Figure 10

CONTOUR AREA AND ANNOYANCE REDUCTIONS DUE TO IMPROVED TECHNOLOGY AT SJC

OPERATIONS: 85% NORTH, 15% SOUTH

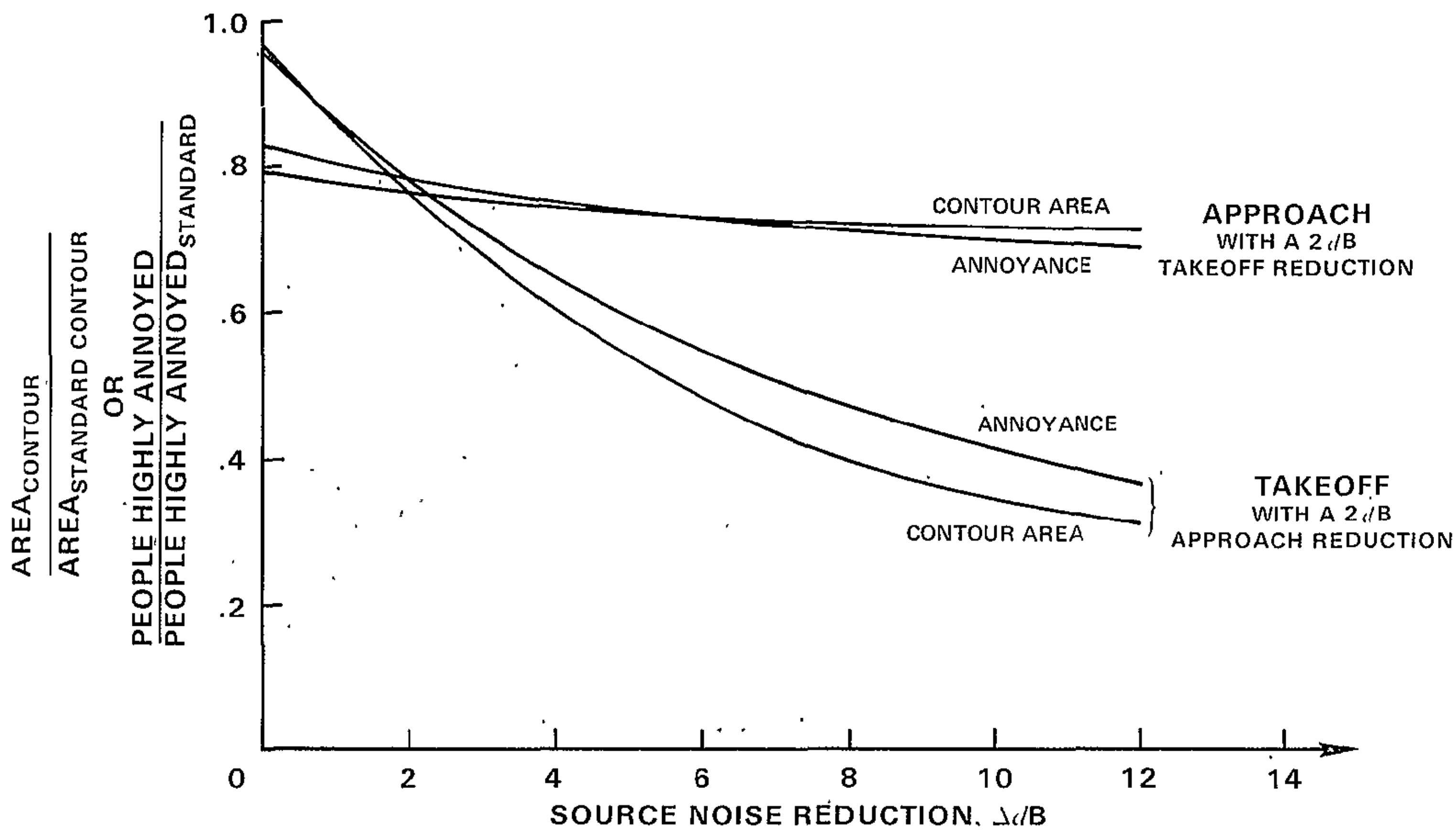


Figure 11

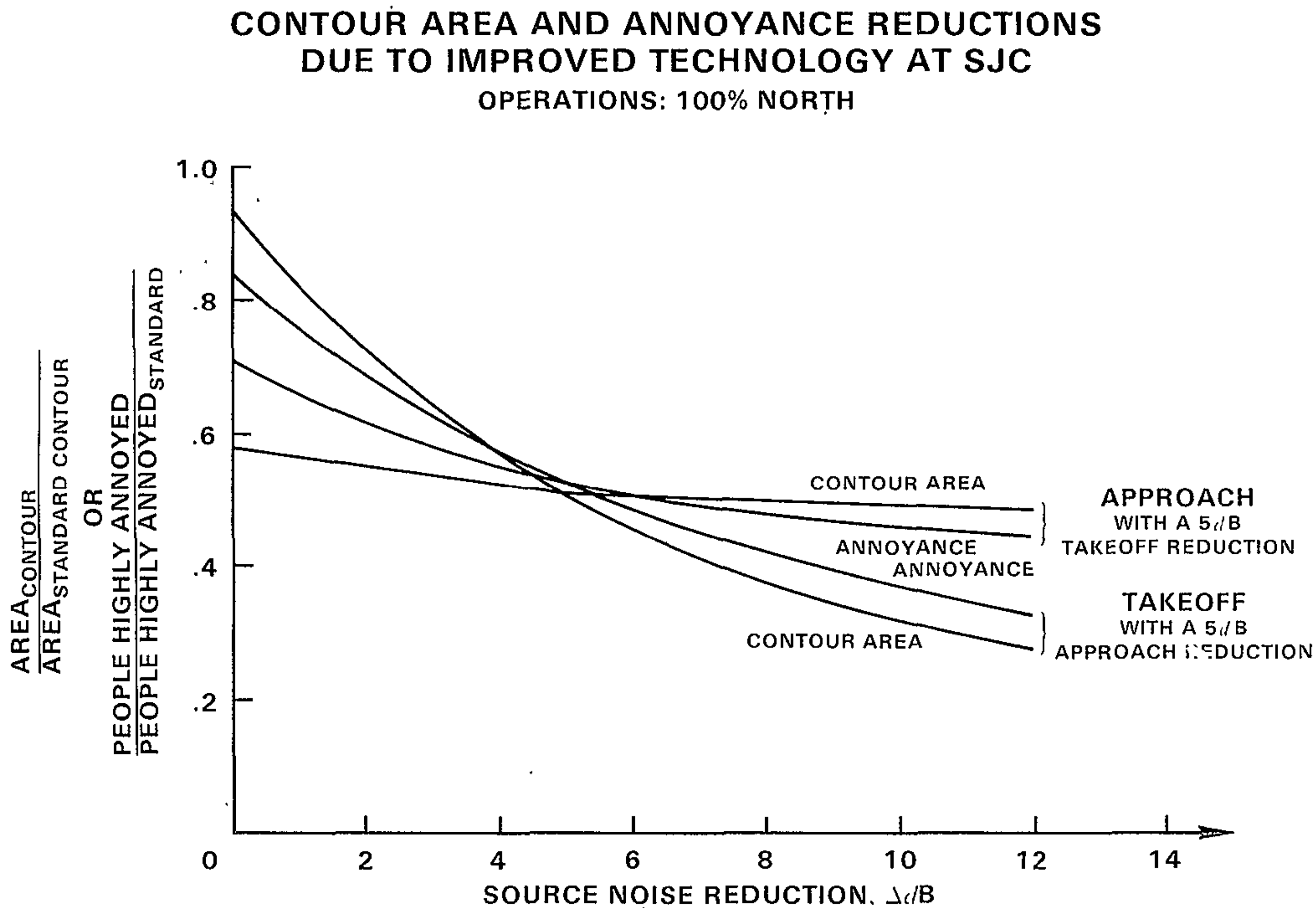

CONTOUR AREA AND ANNOYANCE REDUCTIONS
DUE TO IMPROVED TECHNOLOGY AT SJC
OPERATIONS: 100% NORTH
AREA_CONTOUR / AREA_STANDARD CONTOUR
OR
PEOPLE HIGHLY ANNOYED / PEOPLE HIGHLY ANNOYED_STANDARD
1.0
.8
.6
.4
.2
0
2
4
6
8
10
12
14
SOURCE NOISE REDUCTION, ΔdB
CONTOUR AREA
ANNOYANCE
APPROACH
WITH A 5dB
TAKEOFF REDUCTION
ANNOYANCE
CONTOUR AREA
TAKEOFF
WITH A 5dB
APPROACH REDUCTION

Figure 12

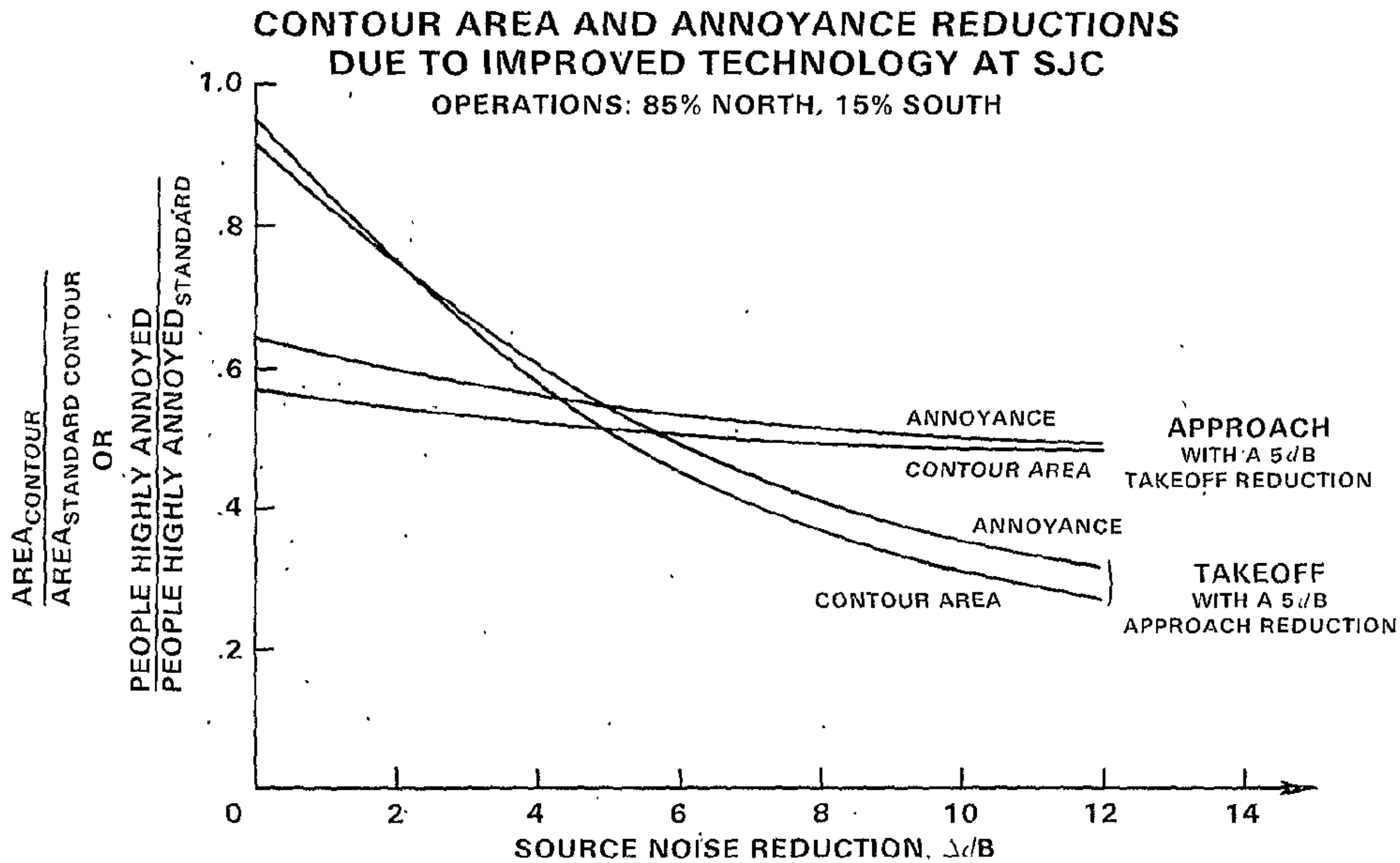

CONTOUR AREA AND ANNOYANCE REDUCTIONS
DUE TO IMPROVED TECHNOLOGY AT SJC
OPERATIONS: 85% NORTH, 15% SOUTH
AREA CONTOUR / AREA STANDARD CONTOUR
OR
PEOPLE HIGHLY ANNOYED / PEOPLE HIGHLY ANNOYED STANDARD
1.0
.8
.6
.4
.2
0
2
4
6
8
10
12
14
SOURCE NOISE REDUCTION, ΔdB
ANNOYANCE
CONTOUR AREA
APPROACH
WITH A 5dB
TAKEOFF REDUCTION
ANNOYANCE
CONTOUR AREA
TAKEOFF
WITH A 5dB
APPROACH REDUCTION

Figure 13

CONTOUR AREA AND ANNOYANCE REDUCTIONS DUE TO IMPROVED TECHNOLOGY AT SJC

OPERATIONS: 100% NORTH

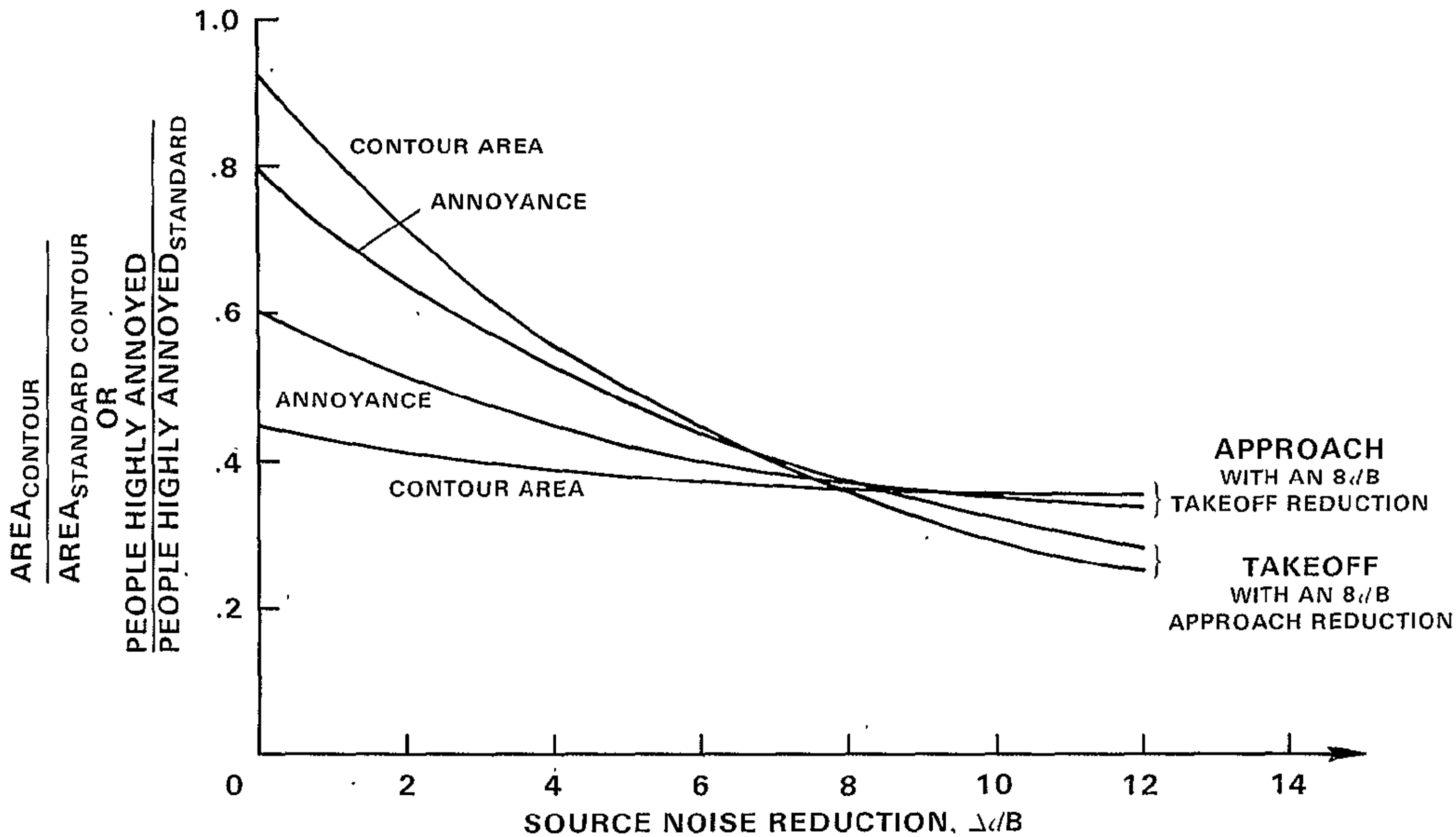
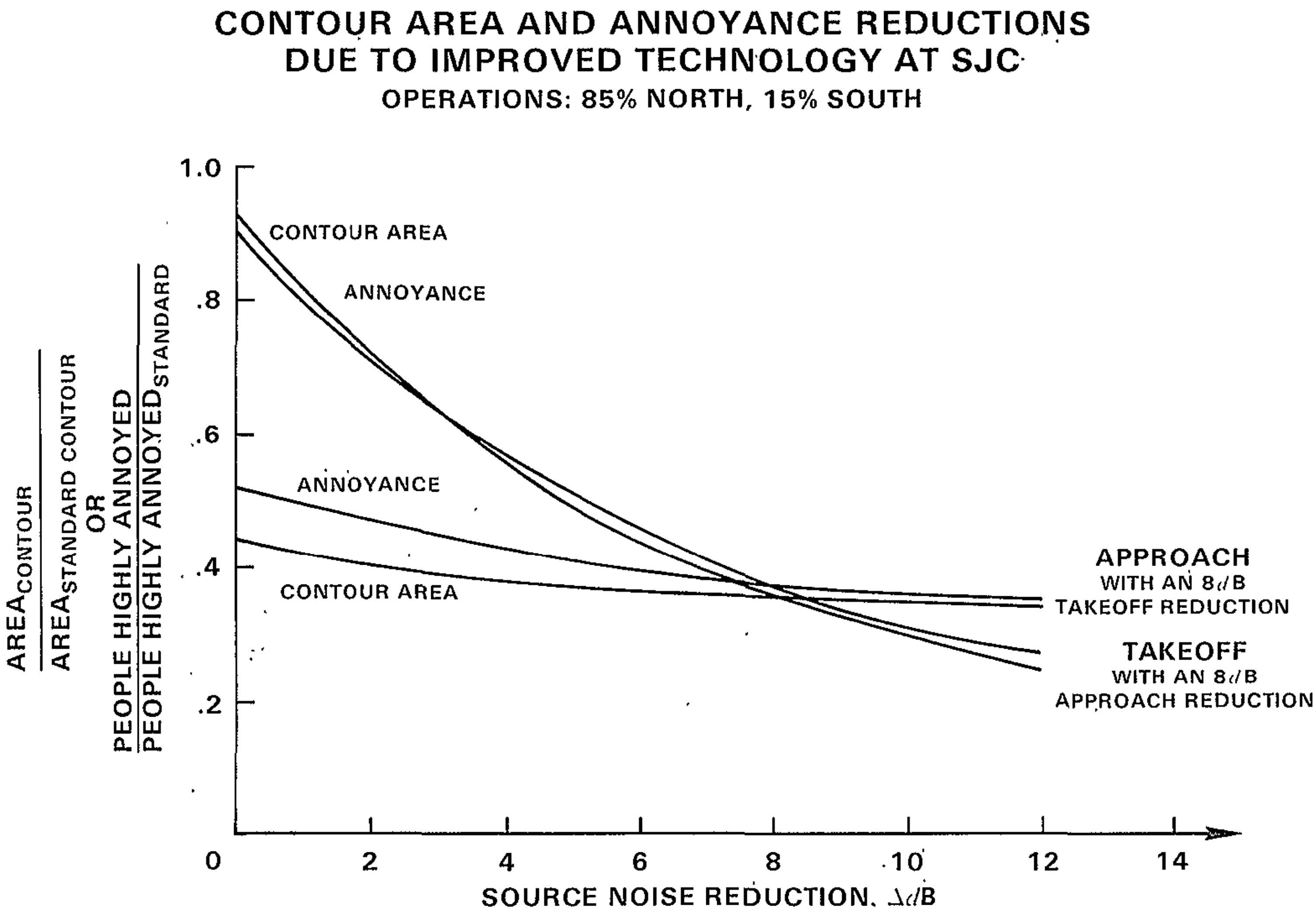


Figure 14



CONTOUR AREA AND ANNOYANCE REDUCTIONS
DUE TO IMPROVED TECHNOLOGY AT SJC
OPERATIONS: 85% NORTH, 15% SOUTH
AREA CONTOUR / AREA STANDARD CONTOUR
OR
PEOPLE HIGHLY ANNOYED / PEOPLE HIGHLY ANNOYED STANDARD
1.0
.8
.6
.4
.2
0
2
4
6
8
10
12
14
SOURCE NOISE REDUCTION, ΔdB
CONTOUR AREA
ANNOYANCE
ANNOYANCE
CONTOUR AREA
APPROACH
WITH AN 8dB
TAKEOFF REDUCTION
TAKEOFF
WITH AN 8dB
APPROACH REDUCTION

Figure 15

CONTOUR AREA AND ANNOYANCE REDUCTIONS DUE TO IMPROVED TECHNOLOGY AT SJC

OPERATIONS: 100% NORTH

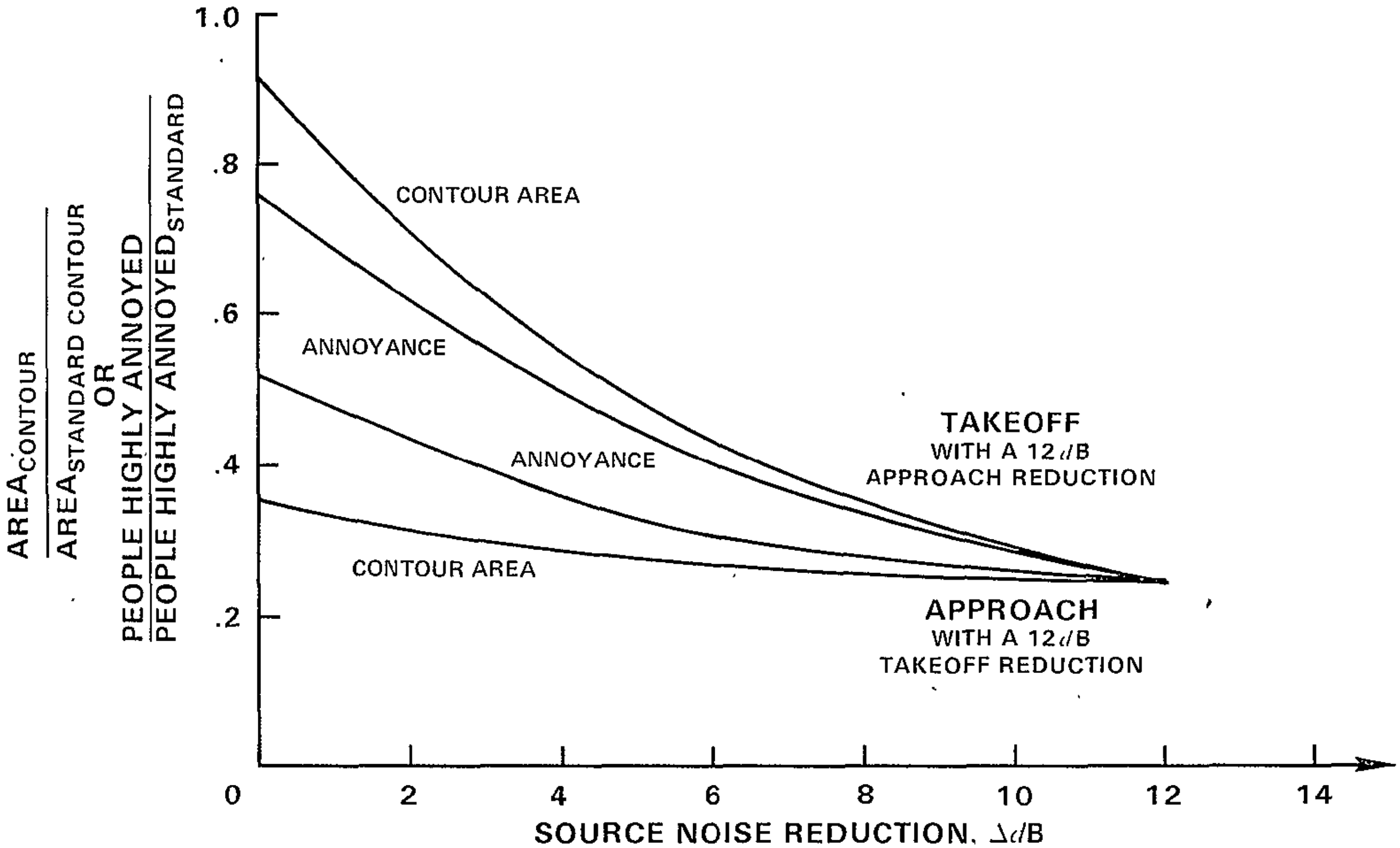


Figure 16

CONTOUR AREA AND ANNOYANCE REDUCTIONS DUE TO IMPROVED TECHNOLOGY AT SJC

OPERATIONS: 85% NORTH, 15% SOUTH

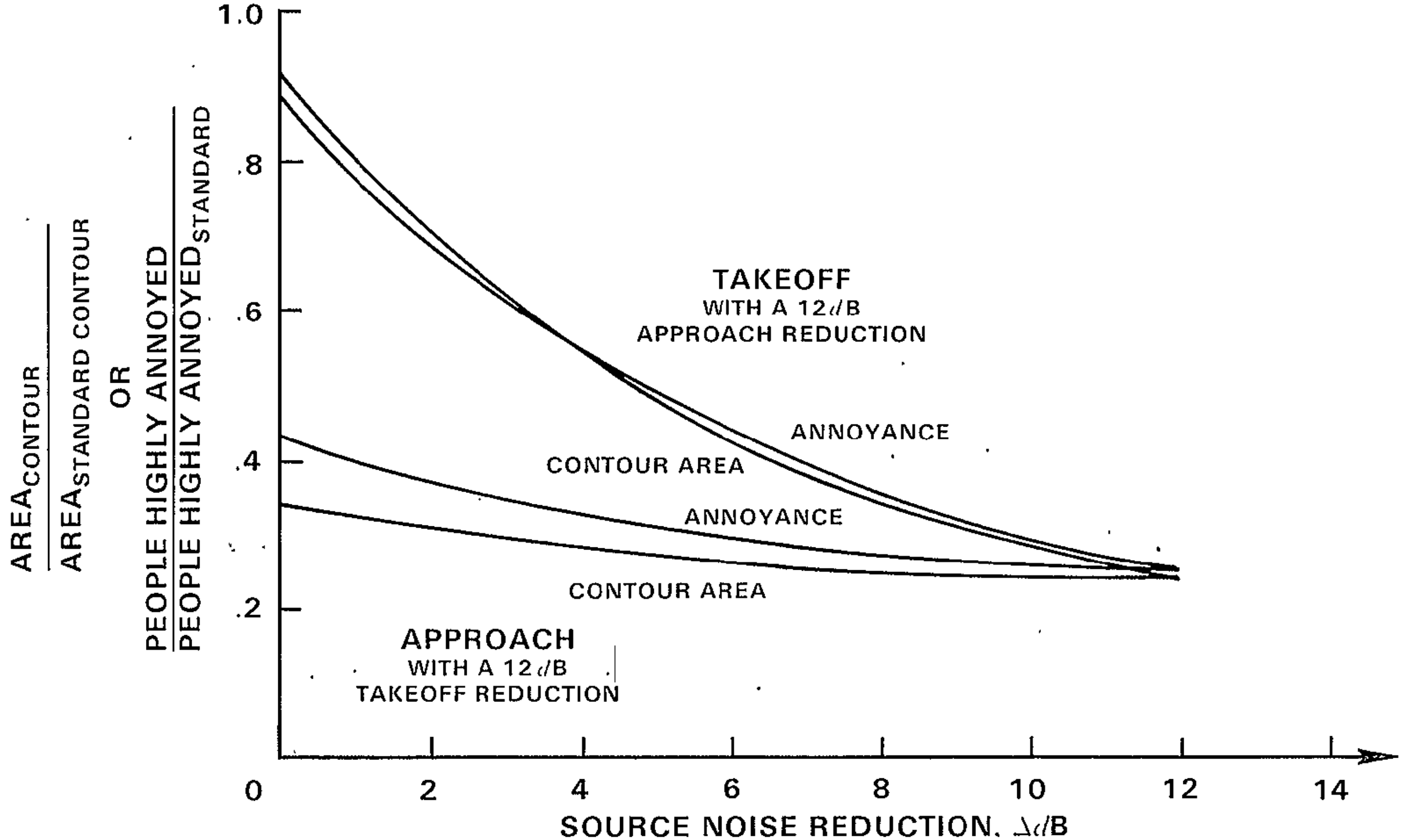


Figure 17

SUMMARY OF POTENTIAL COMMUNITY NOISE IMPACT IMPROVEMENTS

NO. OF DAILY OPERATIONS BASED ON SEPT, 1974 SAN JOSE OPERATIONS
CONSTANT POPULATION DENSITY ASSUMED

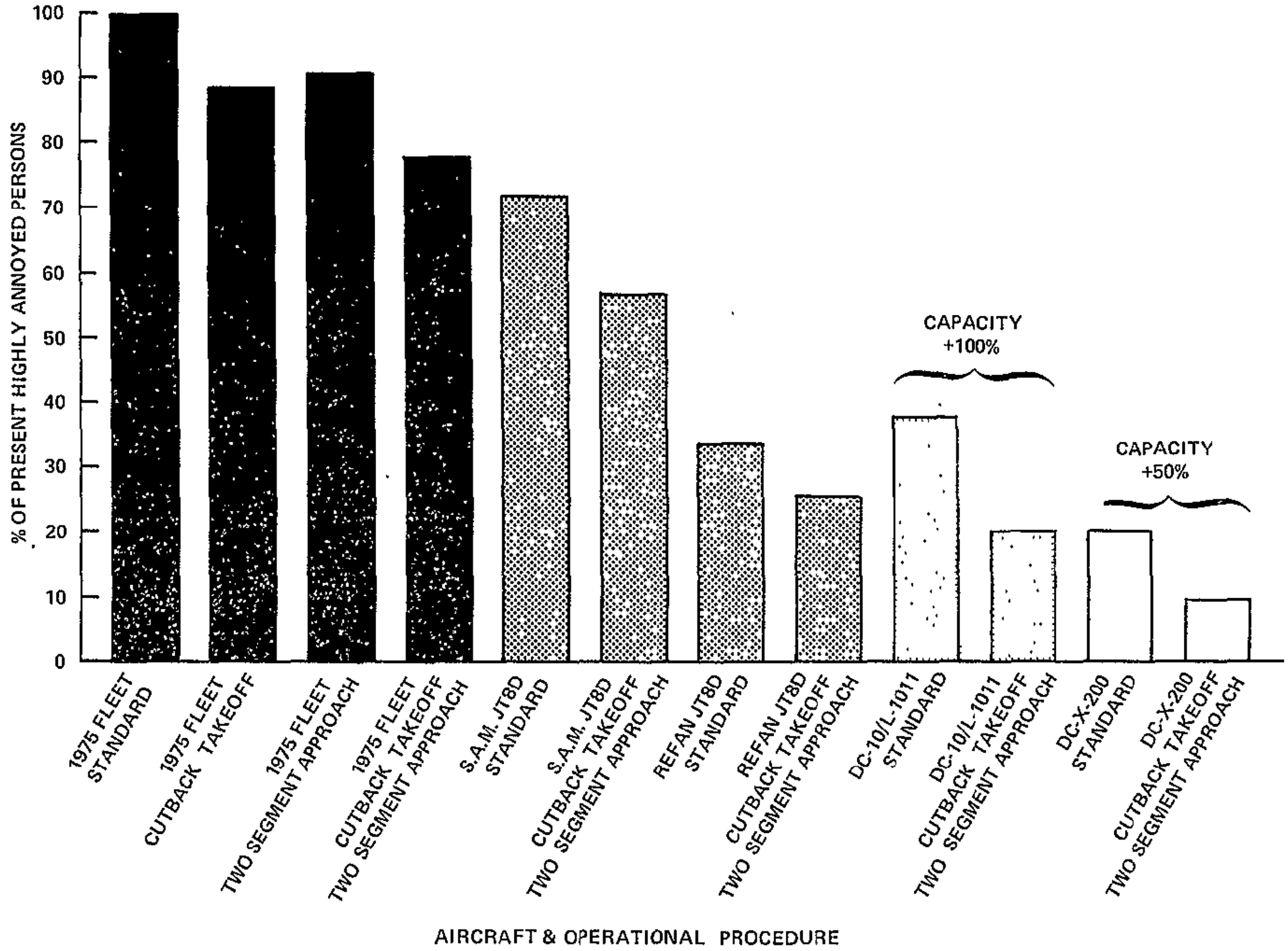
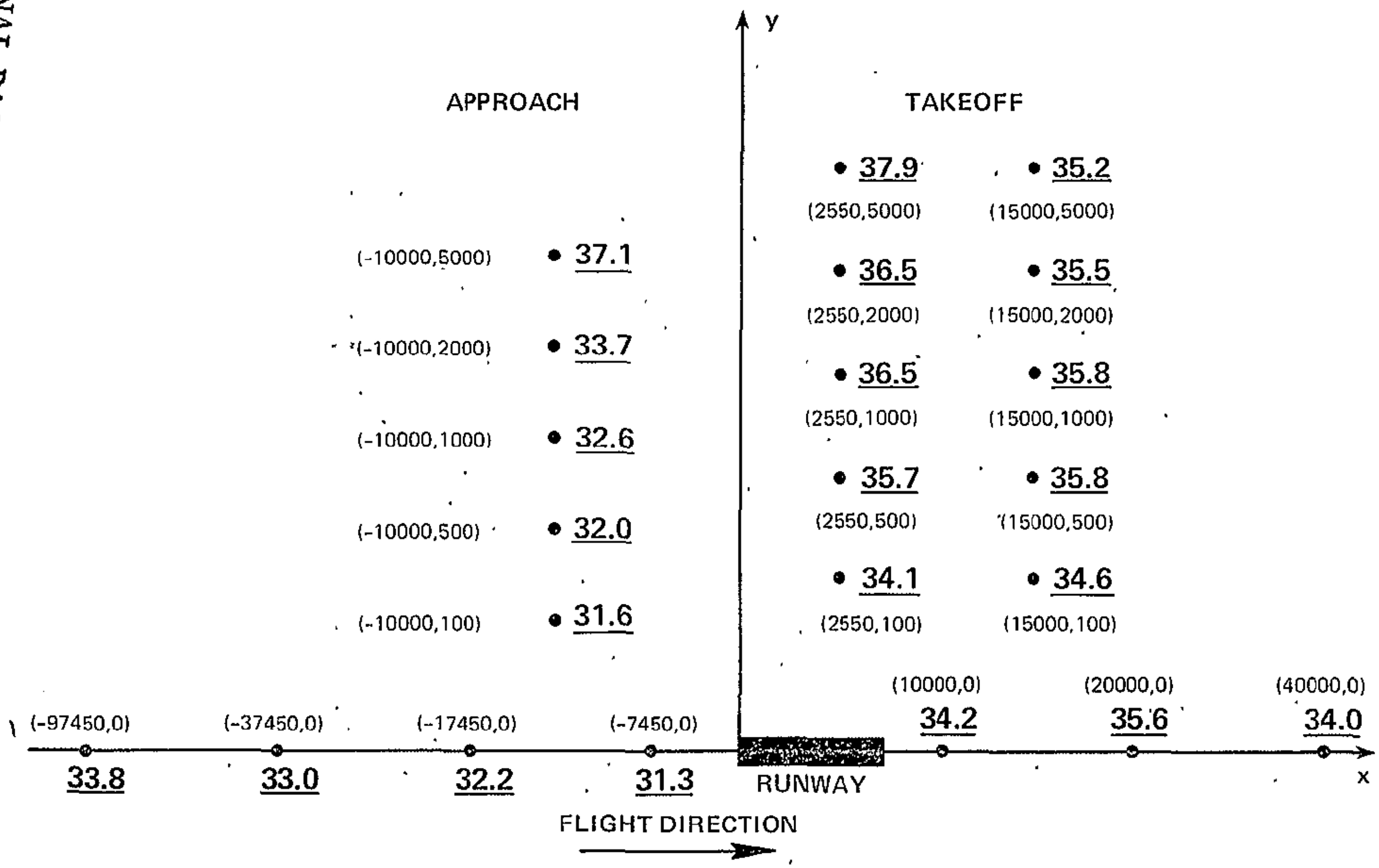


Figure 18

COMPARISON OF L_{DN} AND NEF AT SJC, SEPTEMBER, 1974



NOTE: BOLDFACE PRINT EQUALS (L_{DN} – NEF)
COORDINATES OF POINT IN LIGHT PRINT

Figure 19

APPENDIX

COMPARISON OF NOISE EXPOSURE FORECAST AND DAY/NIGHT LEVEL

Because Day/Night level (L_{DN}) and Noise Exposure Forecast (NEF) are based on different frequency weighting scales, an exact analytical expression relating the two for typical airport operational mixes is not possible.* Using a minimum of empiricism, the derivation follows. NEF is defined as:

$$NEF_i = EPNL_i + 10 \log (N_D + \frac{50}{3} N_N) - 88$$

and L_{DN} is similarly defined as:

$$L_{DN_i} = SEL_i + 10 \log (N_D + 10 N_N) - 49.36,$$

where i represents an individual aircraft type, N_D and N_N represent the number of daytime and nighttime flights, respectively. SEL and EPNL were compared in two ways: (1) from Reference 1, EPNL $\cong$ SEL + 3 or 4 appears to be valid; and (2) from Reference 2 and from analysis of Department of Transportation (DOT) airplane noise data, EPNL $\cong$ dB(A) + 12, and db(A) $\cong$ SEL - 8.4. These relations indicate that EPNL $\cong$ SEL + 3.6. Combining expressions for SEL for a given number of daytime flights gives:

$$SEL = L_{DN} + 49.4 - 10 \log N_D = NEF + 84.4 - 10 \log N_D$$

or

$$L_{DN} = NEF + 35 \text{ for any number of daytime flights.}$$

---

*NEF and L_{DN} could be related exactly using noy tables, given instantaneous values of third-octave band noise levels. However, these indices were designed to quantify the community response to mnay aircraft flights over the course of a day, a situation in which the use of noy tables and third-octave band measurements would be hopeless.

For all nighttime flights,

$$SEL = L_{DN} + 49.4 - 10 \log (10 N_N) \cong NEF + 84.4 - 10 \log (\frac{50}{3} N_N)$$

$$SEL = L_{DN} + 39.4 + 10 \log N_N \cong NEF + 72.2 - 10 \log N_N$$

or

$$L_{DN} \cong NEF + 33.$$

Depending on the mix of daytime and nighttime operations at a particular airport, this indicates that a difference of between 33 and 35 should be used to relate the two indices.

To test this relationship, and perhaps to get a more precise result, L_{DN} and NEF values were compared at points in the vicinity of San Jose Municipal Airport using the NASA/DOT noise contour computer program mentioned earlier. The points chosen were under the takeoff and approach flight tracks, and at sideline points at which the airplane's closest points of approach were 500, 1000, 2000 and 5000 feet. The results are shown schematically in Figure 19.

The difference is somewhat smaller than 35 on approach, but 35 seems satisfactory for the takeoff points. For the approach points, a figure of 33 seems to fit well. Another trend is that the difference becomes larger with distance, particularly for sideline points. This can be attributed to atmospheric attenuation of high frequencies, the range that EPNL weights most heavily. The difference (EPNL - SEL) decreases with distance since the effect of the high frequencies on EPNL is reduced. When 88 is subtracted from $EPNL_i$ to calculate NEF, but only 49.4 is subtracted from SEL_i to calculate L_{DN}, the difference (L_{DN}-NEF) grows with distance (Figure 20). The sideline difference is greater

because the same effect is also occurring with excess ground attenuation.*

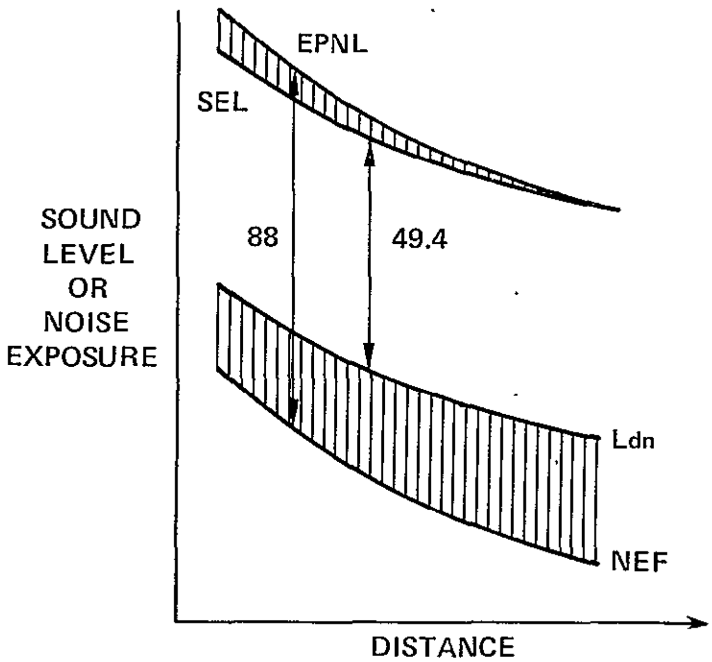


Figure 20

Which index should be used to rate community response? The purpose of these indices (or any noise index) is to provide a means for comparison--between airports, between different operational procedures, or of the noise reduction effectiveness of improved technology (as compared to present noise levels). As long as one index is used consistently, either one will give similar results. Both NEF and L_{DN} are good measures of community response; so in light of the EPA's choice of L_{DN} as its basic measure of environmental noise impact, L_{DN} was used throughout this study.

*The ground actually attenuates low frequencies more than high frequencies. Because neither index weighs the low frequencies greatly, this does not affect their overall values.